

Summer 1971

ADAPTATION TO PRISMATIC ROTATION AS A FUNCTION OF FIELD, EXPOSURE ACTIVITY, AND SIGHT OF BODY PART

EARL SALO STEIN

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72-3732

STEIN, Earl Salo, 1944-
ADAPTATION TO PRISMATIC ROTATION AS A
FUNCTION OF FIELD, EXPOSURE ACTIVITY,
AND SIGHT OF BODY PART.

University of New Hampshire, Ph.D.,
1971
Psychology, experimental

University Microfilms, A XEROX Company, Ann Arbor, Michigan

ADAPTATION TO PRISMATIC ROTATION
AS A FUNCTION OF FIELD, EXPOSURE ACTIVITY, AND
SIGHT OF BODY PART

by

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B.A., University of Maine, 1967

M.A., University of New Hampshire, 1970

A DISSERTATION

Submitted to the University of New Hampshire

In Partial Fulfillment of

The Requirements for the Degree of

Doctor of Philosophy

Graduate School

Department of Psychology

August, 1971

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TABLE OF CONTENTS

| | |
|-----------------------------|-----|
| LIST OF TABLES..... | iv |
| LIST OF ILLUSTRATIONS..... | v |
| ABSTRACT..... | vi |
| INTRODUCTION..... | 1 |
| Historical Perspective..... | 1 |
| The Research Question..... | 49 |
| Design and Hypothesis..... | 50 |
| METHOD..... | 55 |
| Subjects..... | 55 |
| Apparatus..... | 55 |
| Procedure..... | 60 |
| RESULTS..... | 72 |
| DISCUSSION..... | 96 |
| REFERENCES..... | 117 |

LIST OF TABLES

| | |
|--|----|
| 1. Schematic Designs..... | 63 |
| 2. Mean Error for Rotation and No Rotation in Design 1..... | 73 |
| 3. Analysis of Variance for Design 1..... | 74 |
| 4. Simple Main Effects from the AB Interaction in Design 1..... | 76 |
| 5. Mean Error (Degrees) Deviation for Each Activity- Stimulus Combination in the Second Design..... | 77 |
| 6. Analysis of Variance for Design 2..... | 78 |
| 7. Comparison of Simple Main Effects from AC (Activity x Pre-post) Term in Design 2..... | 81 |
| 8. Mean Error (Degrees) for Each View-Field Combination in Design 3..... | 82 |
| 9. Analysis of Variance for Design 3..... | 84 |
| 10. Simple-Simple Main Effects from ABC Term in Design 3..... | 85 |
| 11. Mean Error (Degrees) on Visual Motor Task in Design 4..... | 87 |
| 12. Analysis of Variance for Design 4..... | 88 |
| 13. Mean Error Scores in Design 5..... | 89 |
| 14. Analysis of Variance for Design 5..... | 90 |
| 15. Mean Errors for Design 6..... | 93 |
| 16. Analysis of Variance for Design 6..... | 94 |

LIST OF ILLUSTRATIONS

| | |
|--|----|
| 1. Organization of the Fields above the Pursuit Unit.... | 57 |
| 2. The Apparatus..... | 59 |
| 3. The Fields..... | 61 |
| 4. Bar Graph of AC Interaction in Design 2..... | 80 |

ABSTRACT

ADAPTATION TO PRISMATIC ROTATION
AS A FUNCTION OF FIELD,
EXPOSURE ACTIVITY, AND SIGHT OF BODY PART

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ABSTRACT

Adaptation to Prismatic Rotation as a Function of Field, Exposure Activity, and Sight of Body Part

by

Earl S. Stein

The study of adaptation to prismatic distortion has generated many theoretical controversies since its inception over a century ago. Questions have been centered on two basic concerns, the nature and locus of the adaptation phenomenon. Research theorists have disagreed on whether the process is of a local proprioceptive nature or requires higher level relational changes in various hypothesized neural mechanisms. Among those who believed the process involved alterations in the central nervous system, there are arguments about what specifically occurs and which variables induce adaptive shifts. The purpose of the research reported in this paper was to examine several independent variables which in the past had been ignored or treated in a very different manner. These variables included: the fields to which Ss were exposed, the activity Ss were allowed when examining the fields through prisms, and finally the importance of viewing part of one's body during prism exposure.

Eight Ss were randomly assigned to each of 19 groups in six experimental designs for a total of 152 Ss. Ss used their dominant eyes and hands during the experiment. Each S

was exposed to only one activity--field combination; therefore measures on these two variables were independent rather than repeated. Ss were seated in the apparatus which consisted of three main parts: (1) the prism unit--which rotated the proximal stimuli 30 degrees to the left or right of gravitational vertical, (2) the Lafayette Pursuit Apparatus used to move a point of light around the outside contours of the stimulus field, and (3) a large box type structure housing the other equipment. Measures on the dependent variables were taken from two protractors. The first was mounted on a table surface just beyond S's reach. When S was required to point directly in front of himself, E could read the distance in degrees from true front. The second protractor was mounted behind a bar containing two points of light and located behind the apparatus. As E moved the points, S was required to state when the points appeared vertical.

The first design was accomplished to determine whether or not Ss would adapt to prism rotation. Eight Ss were run in each of two conditions, 30 degrees of rotation versus no rotation. Before and after a 15 minute period of actively tracing the front face of a cube, they were required to align the points of light to the vertical. This was referred to as the visual dependent variable, and it made up the pre-post factor in the subsequent two by two analysis of variance. The analysis indicated that there was no pre-post adaptive shift when the prisms were set at zero rotation. There was, however, a strong shift ($p < .001$) when rotation was employed.

The second design took the form of a three (activity) by five (fields) by two (pre-post) analysis of variance. The

three levels of activity were: passive fixation of the field, paced eye movement around the front contours of the field, and active tracing of the front contours of the field. The fields factor utilized five stimuli: circle, random form, three-dimensional random form, square and cube. The pre-post tests required data from the visual point alignment task. In all activity field combinations Ss viewed part of the dominant hands during exposure. The results demonstrated a strong pre-post rotation effect ($p < .001$).

The third design examined the effects of sight of the hand on adaptation. It took the form of a two (fields) by two (view vs no view of hand) by two (pre-post) analysis of variance. The fields used were the circle and cube respectively. The two groups taken from Design 2 which had seen their hands during fixation of the circle and the cube were compared with two new groups who fixated the same stimuli but were not allowed to view their hands. Results showed that the circle would produce no pre-post shift alone. However, when the hand was added a large shift appeared. The cube was adequate to induce a shift without sight of a body part and the introduction of the hand added very little to the shift magnitude.

Design 4 was the first to employ the second dependent variable known as the visual motor variable. At the beginning and end of exposure Ss in the active condition of Design 2 were asked to point directly in front of themselves while looking through the prisms. The fields were the same as those employed in Design 2. Results provided neither a first to second measure nor a fields effect.

Design 5 examined the effects of vision during the pointing task. The design involved a two (eyes open vs closed) by two (measures) analysis of variance. Two independent groups were employed and both were exposed to the cube stimulus. Results provided no main effect or interactions.

Design 6 consisted of an analysis of data collected from Ss in the active trace condition of Design 2. It concerned the possibility of anticipation effects in aligning the points of light to the vertical. In Design 2 four pre and four post test trials were run. The points were begun in alternating directions such that the last pretest trial and first post test trial were begun from the same direction, the direction of rotation. In Design 2 only these two key trials were analyzed. In Design 6 the two pretest trials which came from the direction of rotation were pooled. The same was done for those from the opposite direction. The procedure was repeated within the four post test trials. The analysis was a five (fields) by two (trials--same, opposite) by two (pre-post) analysis of variance. Both the trials and pre-post main effects were significant ($p < .001$). The lack of interaction between these factors indicated that the adaptive shift occurred independent of anticipation effects.

There were several empirical and theoretical implications from this series of studies. The sources of information from prism adaptation and the reasons for using them are complex. Man responds on the basis of no one fixed rule. He may employ a multitude of cues available to him in the stimulus field for judgments of verticality. An attempt was made to provide a

reinforcement oriented approach to the adaptation process.

A further effort was made at reconciliation between the reafference and information processing approaches to adaptation. It was noted that while the former demanded active, self-directed movement, the latter accepted movement as a potential source of information, deemphasizing the necessity for self direction. This point was important because the information approach (Rock, 1966) required that S know the nature of his own movement even though not directing it. It was theorized that this could be considered vicarious self direction. The general conclusion was that many controversies are largely semantic.

A new experiment was designed to examine the effects of head movement. It utilized a prism system mounted in a helmet, the movement of which E could specify.

INTRODUCTION

Historical Perspective

The earliest mention of prismatic adaptation, and the most traditionally cited, was that of Hermann Von Helmholtz in 1867. His Principles of Physiological Optics was reprinted several times. Helmholtz (1925) noticed that there were certain changes in the ability to localize objects after viewing them through wedge prisms for a short time. In barely two paragraphs, which constituted his entire reference to the topic, he began an area of research which until the twentieth century was largely ignored. This brief reference to adaptation was a pre-indication of several contemporary concerns. First, Helmholtz (1925) noted that there were aftereffects of adaptation upon removing the prisms. This led to a quantifiable, dependent variable when measurement was introduced in later years. Furthermore, the author noted that he found interocular transfer of these after-effects leading him to the conclusion that the adaptive shift was visual rather than merely proprioceptive. This question has been controversial since its inception.

While Helmholtz (1925) had referred to adaptation in the middle of the eighteen hundreds, nothing was done in the area until just before the turn of the century. George Stratton (1896, 1897) made the pioneering studies which led to current interest in the area. Stratton dealt with adapta-

tion of a different sort, for his basic question was concerned with the necessity of the inversion of the retinal image for upright vision. His research paradigm was seemingly simple and yet confounded by many factors, such as right-left reversal. He developed an optical system which could reinvert the image and wore it for various periods of time. The courage displayed by Stratton acting as his own subject and ignoring the threat to his visual system can only be admired. Although his approach was idiographic, it served as a milestone in tampering with the untamperable. The first experiment lasted seven and one-half hours spread over two days. Stratton wore a lens system which rotated the image 180° . The author took no measurements, but kept a detailed log of his phenomenological impressions. He noted for the most part that the world continued to look upside-down, but that he could with effort make a given object appear normal. There were no aftereffects reported from this experiment, however. He assumed that if he had no previous visual experience then the optics would have produced no distortion, for a normative state of perceptions and relations was a precondition for adaptation. In the second experiment Stratton (1897) served as his own S for eight days with a total exposure time of 87 hours (exposure is the term currently in use for referring to those periods ss actually look through the optics). The author felt his adaptation in this experiment was faster than that of his first effort, because of his previous experience with inversion. As an indication of the relevance of stimulus information, Stratton

apparently used whatever was available. For example: he compared the contours of his shoes to determine which was his right foot and which was his left; this was no doubt difficult because of the right-left reversal in addition to inversion. Stratton (1897) began several of the contemporary theoretical concerns in perception and cognition.

He spoke of the difference between preexperimental and new visual imagery. When he could maintain his new pattern of localization, things appeared normal, but when he lapsed into preexperimental memory of how things used to appear, the scene looked strange; he felt his body was upside down. Upon removal of the lenses, the field looked upright but again strange for a while. Stratton made motor errors and felt nauseated. Stratton (1897) believed that the major problem introduced by the optics was a discrepancy between visual directions suggested by sight and the visual directions suggested by touch. He ascribed to the then popular doctrine of local signs, accepting that the perceiver had to build up a set of relations between local tactual signs and corresponding signs in vision. These signs had come, according to Stratton, to mean the same thing. When wearing lenses this "harmony" was destroyed, because initially the old tactual signs stimulated those from preexperimental vision, which were no longer appropriate. These were suppressed, not destroyed, and new signs temporarily supplanted them. This would account for the rapid recovery after adaptation. The concept of harmony between vision and touch and the use of memory in adaptation

would be used by later theorists (Held, 1961; Held & Freeman, 1963; Rock, 1966; Kohler, 1964; Gibson, 1966). Stratton, the early phenomenologist, was followed by theorists and experimenters of many orientations, few of which until recent years have appeared in as many bibliographies as he. Over thirty years passed before anyone picked up the research challenge.

It was Ewert in 1930 who attempted to add a quantitative thrust to Stratton's earlier research (Snyder & Pronko, 1952). In contrast to other work, like that of Stratton (1896, 1897) and Kohler (1964), this experiment is often cited as evidence that adaptation to inversion does not occur (Rock, 1966). The period of exposure was extended to 14 days and three SS, including Ewert, were used instead of only one. Ewert used a binocular device for reinverting the image. Since this interfered with the normal convergence of the eyes, depth cues were probably distorted and double images present when stimuli were close at hand. Several quantifiable tasks were employed. On the back of each hand a grid was printed, and SS were required at alternate times to touch one coordinate immediately after it was tactually stimulated or name the spot without being able to see it (Snyder & Pronko, 1952). SS did reduce their errors over time but no one reported that the field looked upright. In general, Ewert found no aftereffects of adaptation. Rock (1966) noted that SS were occupied primarily with their tasks and probably had little time to explore the field. That, coupled with the problems induced by the optical device, could account for the lack of aftereffects following

such a long exposure. Ewert's attempt at quantifying adaptation to inversion was a necessary first step, although the results were not heartening. Inversion, however, by its very nature is a difficult phenomenon to study. It either goes to completion or it does not. You either obtain a subjective righting of the field or you do not. There is no half-way point indicative of changes which are less than total. In contrast, both rotation and displacement provide the opportunity to obtain partial shifts and to quantify the magnitude of the effects. This is one reason why so much more has been done in the other areas of adaptation, such as displacement.

About the same time that Ewert was beginning his research, J. J. Gibson (1933) was starting a program of investigation involving prismatic displacement. He noted that his ss adapted to the displacement of images. They also adapted in time to the prism induced curvature of the stimuli. This curvature is one of the side effects of displacing prisms. Gibson (1933) became more interested in curvature than in his previous concerns. When allowed to touch a meter stick and examine it through prisms, the kinesthetic feedback did not alter the adaptation. Rather, ss reported that the stick "felt" curved, and Gibson (1933) concluded that vision was a dominant system. He noted this was in contrast to Stratton (1896, 1897) who believed that touch was the route to "reality" and therefore the key perceptual system. Gibson (1933) found that ss, who were required to sit motionless, still showed a perceptual change. This was the first reference to the active-

passive question and the investigator assumed that a motionless S was passive, a common fallacy in later research.

The main conclusion drawn by Gibson in the 1933 study was that optics were unnecessary for the study of adaptation. He noted that ss who examined a curved line viewed it as less curved over time. The same effect occurred for the rotation of lines. Gibson (1933) found it necessary to relegate adaptation to a local sensory process not involving any conflict between vision and other modalities. In doing so, his efforts had the historical effect of shifting interest for many years away from prism adaptation (Rock, 1968). He based some of his early conclusions on such evidence as the apparently small effects of eye movements in his paradigm of line examination. ss who explored lines freely did only slightly better than those instructed to fixate on the stimuli. Ewert (1937) noted that even in fixation ss probably made many small compensatory eye movements. Today we do not know how well his ss obeyed the instruction to fixate. We do know that eye movements can be informative within limits (Ludvigh, 1952). We further know that all Gibson's (1933) effects were of small magnitude and no statistical evidence as to their significance was provided.

It seems possible that many current investigators have misread Gibson (1933) or only read him in part. These include Rock (1966), Mack (1966), Held and Hein (1963), Mack and Rock (1968) among others. In the latter part of the article he noted some interesting conclusions. To that point

it appeared that he was building an analogy between his localized line shifts and color adaptation. He stated, however, that adaptation to curvature produced interocular transfer, which of course color adaptation does not. This led him to the reluctant conclusion that the effects had to be at some higher level than retinal. Morant and Harris (1965) concurred with this. The "local sign" approach subscribed to by Stratton (1896, 1897) was unworkable. Gibson (1933) concluded with a Gestalt-like approach, indicating that there was a plastic set of correlations or relationships between the retinal stimulation and phenomenological experience which can be altered by the adaptive process.

Gibson (1937) is often cited as an indication that some local process exists which must be factored out of the main adaptive shifts. The author was simply trying to emphasize a need for the study of line perception, an area previously uninvestigated. He admitted that reduction to a physiological theory at that time would have been premature and would stifle research by limiting its less reductionistic efforts. Gibson (1937) posited the idea that any modality could show adaptation with negative aftereffect if an "opposition series" was available. The latter refers to a continuum with two opposite ends and a neutral point somewhere in between. For example: in adaptation to a tilted line the neutral point would be true vertical and the opposite directions of tilt, the two end points of the continuum. The prolonged exposure of any stimulus quality may modify the effects of all other stimuli

in the series. This concept bore a great similarity to what was to become Helson's (1951, 1954) adaptation level theory.

Gibson's (1937) study with tilted lines showed that the adaptive shifts producible with his technique were rarely over two degrees. This amount was not in excess of the average error of ss in pretests in Witkin, Lewis, Hertzmann, Machover, Meisner and Wapner's (1954) study, where the only task was to align a rod to the subjective vertical without any previous exposure to tilted lines or fields. It would seem that Coltheart (1971) has appropriately handled Gibson's (1933, 1937) work. Coltheart (1971) viewed Gibson's research as not even being in the same area of concern as the majority of adaptation research. It was in effect concerned with line perception and the retinally-localized aftereffects of examining lines in specific orientations. Coltheart noted that adaptive shifts are often interocular and do not diminish appreciably as the stimulus is focused on a new retinal location. In contrast, a slight change in location can literally obliterate Gibson's effects although Gibson did report some interocular transfer. Gibson (1933, 1937) explained his results in terms of the normalization hypothesis. Inspecting a tilted line changes the norms of the major horizontal and vertical axes. Thus when a vertical figure is examined, it appears tilted in relation to the shifted norms. Coltheart (1971) offers an alternative explanation in terms of specific contour detectors located in the retina as discovered by Hubel and Wiesel in 1962. A weighted average of the responses of such units provides a

phenomenal experience of a line in a specific orientation. When examining a second line, perception is nonveridical because the weighted average is distorted by the decreased effectiveness of those units which responded to the specific orientation of the first line. This explanation has a modern flavor and will no doubt be of use to those investigators concerned with local Gibson-type effects.

Ivo Kohler renewed interest in the area and indicated that prism distortion was simply a systematic way of manipulating proximal input. The proximal image of a line tilted 30° and that a line optically rotated (by a well-designed optical system) are the same. The advantage of prisms is that they allow a more holistic distortion, providing a consistent alternation of everything that the Ss see.

Kohler (1964) began his work at Innsbruck in the early thirties. His monograph was published in German well before the English edition appeared. He waited thirteen years to be sure of his data before allowing the American printing and it was J. J. Gibson who wrote the introduction to that edition. Gibson (1964) recalled his work of thirty years past and noted that Kohler's investigations were more far reaching. What Kohler was doing was providing a systematically biased retinal input, the proximal stimuli of which still carried information about the environment but in an altered form (Gibson, 1964). Kohler (1964) struck a theoretical median between behaviorism which only examines adaptive behavior and pure phenomenology where measurement is all but impossible. While presenting

a theory of adaptation that is motor oriented, Kohler was by no means an arch motor theorist to the exclusion of all else, stating that the return of normal perception in adaptation must be based on more than the mere restoration of motor skills. Gibson (1964) stated that in his research the Ss had stimuli imposed upon them, while in Kohler's work the whole visual exploratory system was involved, and Ss had to actively obtain stimulus information. In emphasizing a relationship between proprioception and vision in perception, Kohler's theory was not only novel but provided evidence contrary to such approaches as the camera theory of visual perception which only considered the relationship between the retina and perceived objects.

Kohler's theory can be stated in relatively simple terms. Several characteristic experiments from Kohler's research program will serve as an introduction. Kohler (1964) stated that Stratton had provided a new methodology of "experimental disturbance" which made it possible to study perceptual formation as it develops. An attempt was made to replicate Stratton's work, using better apparatus and some primitive efforts at assessment. It was found that motor abilities were the first to adapt. When allowed to touch a familiar object, Ss reported that it appeared right side up. Vestibular information such as that provided by driving uphill in an automobile also assisted a phenomenological impression of uprightness. The author noted that familiar objects and those containing specific information like smoke rising from a chimney were

seen as right side up more frequently than neutral or unfamiliar stimuli. As far as inversion research, Kohler's results are unique in that no one else has reported a clearly defined righting of the field. It seems that most ss become comfortable with it but that it still appears inverted. As long as they do not think about it, there is no problem, however (Stratton, 1896, 1897).

The type of experiment that really brings out the basic tenets of the theory involves dual simultaneous stimulation to the eye from such devices as split spectacles. Kohler (1964) wondered what would occur if half of each retinal field was predominantly exposed to one distortion and the other half to another or no distortion at all. This idea came from his wearing wedge prisms himself for four months. He noted that the aftereffects seemed to change as he moved his eyes from one direction to the other. A pair of glasses was devised which held prisms in the top of each lens and plain glass in the bottom. During initial adaptation ss got aftereffects in the bottom half of the field when they looked downward. These gradually disappeared and the experience became a unified whole until the optics were removed. At that point ss perceived a negative aftereffect (displacement in opposite direction of prisms) when looking up and no effect when looking down. It must be remembered that the entire retina was exposed to distortion, for obviously the ss did not maintain a straight ahead fixation, and yet only the top half of the field showed

an adaptive shift.

This is the "situational aftereffect", which is the key contribution of the empirical work behind the theory. Kohler (1964) explains this by reference to the total stimulus situation, which must include non-optical qualities. Changes in the position of the eye can affect what we see. It is possible that adaptation involves a change in the way the eyes register information due to a change in the relationship between the retinal stimulation and the status of the oculo-motor system. In the full prism experiment, distortion was consistent and systematic across all situations (changes in eye position and/or head orientation). When you use a half prism, you break this up, providing systematic distortion in one situation, upward eye position, but no distortion in the other, downward eye position. A similar effect can be provided with colored lenses, the left half being blue and the right half yellow. After adaptation everything appears achromatic, but the after-images are directly related to eye position. That the oculo-motor system can provide information on the position of the eyes was demonstrated by Ludvigh (1952). With no visual cues SS correctly determined the direction of their gaze, which was only 6° from straight ahead, seventy-five per cent of the time.

Kohler (1964) noted that retinal areas probably build variable traces (an early reference to a storage mechanism) with the other parts of the visual system so that a given stimulus on a certain retinal point can mean two different things depending on the status of the rest of the system.

This research has been criticized by some (i.e. Fishkin, 1968) since its publication. Kohler (1964) used few ss and simplistic measurements. To assess adaptation to inversion for example, ss were shown the letter "M". If it was reported as such, adaptation was inferred; but if it was seen as a "W", then no adaptation was accepted. What the critics like Fishkin (1968) forgot, however, was that research must be judged not only by current standards but by the context and time of its inception. Kohler's work renewed interest in prismatic adaptation and its usefulness in crossmodal research. It was further an early introduction of motor oriented theory at a time which seems in retrospect very appropriate. Kohler (1964) referred to the behavioral change in adaptation as the "stepping stone" for perceptual change. He introduced the early conceptions that would lead Rock (1966) and others to an information-based orientation to adaptation. Man learns to account for the optics and tune out extraneous information.

Another motor oriented approach to adaptation was sensory-tonic theory (Werner & Wapner, 1955). Werner and Wapner (1955) drew comparisons between their concerns and those of the workers at Innsbruck, and they must be credited with a reemphasis of the crossmodal relationship between vision and proprioception. Theirs was an attempt to discuss Kohler's situational aftereffects in terms of their own approach. They noted that most theories would not be too disturbed by motor adaptation. The visual phenomenological shifts, however, were seldom correctly interrelated with the status of the perceiving

organism. This includes not only his tonus distribution but also motivational and emotive factors. They proceeded to ignore these last two items in a brief summary of their theory, the key point of which is that all stimulation is both sensory and tonic in nature. This dichotomous distinction is questionable on several grounds. Allport (1955) noted the absurdity of this distinction. How can tonic changes be other than sensory and perceptual if they provide information? It is likely that each can not be altered without simultaneously affecting the other. In their original experiment Werner and Wapner (1952) defined a sensory event in terms of an auditory or visual stimulus and a tonic experience in terms of a vibration on the neck. Obviously, the latter provides sensory-perceptual feedback and the former could easily affect the muscle tonus distribution. It was, however, the orientation that counted. Essentially it amounted to the belief that an organism can use information from different modalities to reach the same phenomenal experience. How did this apply to Kohler (1964)? Werner and Wapner (1955) felt that perception consists of a relationship between an object and an organism. In a given perception as when an S perceives an object as truly vertical when it is actually so, the organism has developed a stable sensory-tonic distribution. A set of tilting prisms, however, disturbs the normal relationship between S and object. This leads the organism to shift his sensory-tonic status towards a new stability to bring it in line with the new proximal stimuli. Thus when the prisms are removed, the new relation-

ship is again out of place and the S must seek the old distribution. What all this amounts to is just a motor-oriented description of adaptation, obviously not an explanation.

In the early fifties, two investigators at Dartmouth College developed a learning approach to adaptation with emphasis on the motor aspects. Snyder and Pronko (1952) exposed one S to inversion for thirty days. Their optical system was binocular, corrected for spherical and chromatic aberration. The binocular system led to double images at certain distances due to interference with the natural convergence of the eyes, a problem which had led Stratton (1896) to use a monocular apparatus. Snyder and Pronko (1952) differed from Stratton, however, in that they compared the performance on a series of motor learning tasks before, during and after prism exposure. This was a novel approach and has not been used before or since. They found that before exposure, the S's latencies and errors in such tasks as the Purdue Pegboard were quite small but increased drastically during initial exposure. Over the thirty days, however, latencies and errors were reduced. The investigators concluded in contrast with Kohler (1964) that adaptation was simply perceptual-motor learning. They further stated that man learns to see and no inherited perceptual abilities exist with the exception of a very basic and physiological phototropism (Snyder & Pronko, 1952, p. 112). As to the question of whether things ever appeared right side up during adaptation, the answer is not clear. Apparently the observer became comfortable with the

experience as long as he was not forced to compare it with the pre-experimental situation. Here again we see reference to memory, a trend which persists across many theories. A major criticism of this research, however, was its idiographic nature. It seems that even in the early fifties, this area of research had advanced beyond that stage. The work of Snyder and Pronko (1952) serves as but another link in motor approaches to adaptation, the next being the theory of Dr. Richard Held and his associates.

In discord with the trial and error learning approach, Held and Gottlieb (1958) stated that adaptation could occur without the observer obtaining any knowledge of his errors. It must be noted that much of Held's work is in prismatic displacement and none in inversion. He, like most of his contemporaries, seems to accept that all adaptation functions on the basis of the same mechanisms. In order to compare approaches the least that must be accepted is that the mechanisms have something in common. Held and Gottlieb (1958) developed a technique for studying displacement effects. During exposure to a wedge prism, all that an S could see was his hand, no stimulus fields beyond. During the pre and post tests, S's task was to mark the corners of a square which he saw in a mirror. He could see neither his hand nor his responses. The authors found aftereffects in the opposite direction of the prism displacement. The magnitude of these was somewhat related to the movement required during exposure. Organized systematic movement (i.e. moving hand back and forth, once

per second) produced larger shifts than haphazard hand movement.

Research with displacement led Held and his coworkers to an approach known as the reafference hypothesis (Held & Hein, 1958). This was to open up a whole subarea in adaptation, the so-called active-passive question. Held and Hein (1958) found that Ss exposed to fixation of their hands and those who watched as the S moved their hands in the field demonstrated no post-exposure shifts. In the active group where Ss moved their own hands, a shift did occur. This indicated to the Held group that some feedback from self-directed movement was a necessary condition for perceptual adaptation to displacement.

In a developmental study with kittens, Held and Hein (1963) examined the necessity of activity for normal perceptual development. The authors believed that a variation in visual input must be accompanied by self directed movement for the building of normal groups. In the active group Ss walked in a circle in a striped cylinder while harnessed to a boom-like device which kept them in the path and moved a small gondola at the other end of the boom. The passive cats rode in this device. Dependent variables included paw placement, avoidance of the visual cliff, and blink response to approaching objects. The responses of the active cats were quite normal. They consistently avoided the deep side of the cliff, blinked for objects, and stuck out their paws to meet the edge of an upcoming surface. The passive animals failed in every way,

although they had been exposed to the same visual stimulation but limited in activity. Assuming that adaptation and perceptual development are similar, or function with the same mechanisms, the author saw this experiment as analogous to the prism studies. This assumption may or may not be valid. Modifying an adult's perceptual system may be based on different factors than building the systems of an infant.

Held (1961) and Held and Freeman (1963) developed the theory of the reafference hypothesis in a more structured form. Stability of perception was seen as a function of self-directed movement in a stable environment coupled with consistent reafferent feedback. This feedback in normal circumstances agrees with the results of previous actions in the same environment. This is why when one turns his eyes or head the environment does not seem to move. The central nervous system takes note of the fact that an efferent signal was sent out to move and that the reafferent information matched it, indicating that the commanded move had been accomplished. Held (1961) postulated a memory mechanism where the results of correlated efferent-reafferent signals are stored. This mechanism is hypothesized to retain traces of previous combinations of efferent and reafferent signals. When an efferent signal is produced, it activates the appropriate correlated pair in storage. When reafferent input is received, it is compared with the stored results of previous experience in a mechanism called the comparator. The results determine what is to follow. If the reafference agrees with that previously linked to a

given efferent impulse, then no changes are required. If not, the system sets about the task of building new correlated relationships. This is Held's (1961) model for adaptation. These new combinations will be stored and the old ones suppressed. Recency favors the new relationships as adaptation progresses, although initially the old and the new will conflict.

Held and Freeman (1963) refer to the sensory-motor control system. A change in this control system is required for adaptation to occur. What prismatic distortion of the proximal stimuli can accomplish is to disturb the normal relation between motor output and sensory input in a stable environment. Reafferent feedback is predictable from bodily movement only on the basis of two assumptions: that some stimuli in the environment are stationary and that muscle changes produce the same movements in all circumstances. This does not invariably hold. If the body is not in contact with an object or a counterforce (i.e. gravity), muscle changes may not be well related to body movements. Thus, decorrelation of efference and reafference can occur because of sensory deprivation as well as optical distortion.

Held and Freeman (1963) used a variable displacing prism which constantly altered the direction and extent of displacement. Ss' ability to mark the corners of a square as in the Held and Gottlieb (1958) study became less accurate. Ss' response variability was high on the meridian (left-right or up-down) where the prism had been varied. Any effort to

disturb normal efferent-reafferent relationships demonstrates a corresponding breakdown in perceptual abilities, according to Held and Freeman (1963). If the S remained passive, there were no efferent-reafferent links produced and therefore no breakdown. Only active SS suffered the aftereffects. You can only decorrelate feedback when you have efferent output in active movement, according to these researchers.

As an additional effort to bolster their position Held and Rekosh (1963) hypothesized that more was involved in Gibson's (1933) results than simply prolonged viewing of a stimulus coupled with local sensory changes. If this were true, they thought that a curvature aftereffect might appear even if SS were exposed to an environment containing no lines which could be optically curved. This would prove, according to these investigators, that reafference was a sufficient condition for adaptation. Here was one of the very few attempts in this entire area of research to control the stimulus fields. In previous experiments SS wore prisms in uncontrolled environments where normal contours of walls and objects were available. In this study, a stimulus field was employed that consisted of small irregularly shaped spots, randomly distributed. SS were placed in a large cylinder, the inner surface of which was covered with the random pattern, and told not to look at their bodies. A total of eight SS were run with repeated measures across the active and passive conditions, walking in the former condition and being pushed in a wheel chair in the latter. Only active SS showed curvature aftereffects as

measured by having Ss adjust a variable prism until a grid of lines appeared uncurved. The passive group did show some changes but these were not significantly greater than a control group which wore no prisms during exposure. The authors indicated that all that had been necessary for adaptation was a change in the relationship "between self-produced movement and its concurrent sensory feedback" (p. 723). Several possible problems are involved in this study. As usual there was a small number of Ss. Ss were told not to look at their own bodies. This instructional set may not have been adequate to prevent Ss from using all the available information.

Mikaelian and Held (1964) attempted to generalize the results achieved earlier with displacement to an alternative form of optical transformation, namely rotation. The authors felt that full compensation to prismatic rotation would require reafferent feedback provided by active movement. Twelve Ss were exposed to both active and passive conditions in a repeated measures design. The authors admitted that their optics not only served to rotate the image but also displaced the field a few degrees left and up. Two dependent measures were used: aligning a luminescent line to the vertical and aligning the body with two luminescent points one at a time. This was done by instructing Ss to report when the first point was seen as directly in front and lined up with the median planes of his body. The same procedure was followed for the second point which was below the first. The E then drew an imaginary line between the two points and measured its distance from the

vertical. This test was seen as a measure of egocentric vertical, a term meaning something on the order of a perception of body vertical as distinct from field vertical. This distinction was also made elsewhere by Rierdan and Wapner (1966) and Rock (1966). In the first exposure active Ss produced a 6.8 shift for the line and 7.0 for the points. In the passive condition, the change was only 1.9 . Three Ss who were selected on the basis of their rapid adaptive ability were given two hours of exposure instead of only one. Their active and passive scores were 19.6 and 2.7 respectively. A shift of 19.6 is uncharacteristic of other studies in the area and has not been replicated. While Mikaelian and Held (1964) use it to support their major thesis, the result is by no means generalizable because of the minute number of Ss and their preselection on the basis of adaptive ability. The investigators attempted to explain the shifts in the passive condition with the Gibson effect. They reported, however, no attempt to assure the "passivity" of the Ss; and furthermore, they did not produce any statistical contrast between the passive group and a corresponding control group, which could have been exposed to the same environment without prisms. Their explanation based on the Gibson effect amounted to only stating that the magnitude of error was comparable to that found by Gibson (1937) without prisms.

In a second experiment, these researchers attempted to eliminate the grid-like patterning of their previous loose exposure conditions. In an effort at stimulus control, Ss

were placed in a room where all they could see were 99 dimly lit spheres. In this environment, active shifts were only 2.1° and 1.8° (both significant from zero, $p < .01$) for the line and points respectively and passive shifts were "about zero (p. 262)." Mikaelian and Held (1964) then relegated the results of their entire first experiment to the Gibson effect. This is all difficult to accept. It seems obvious that if you impoverish stimulus information to the point that there is no way for Ss to learn the nature of the distortion, then no adaptation can occur. Furthermore, there is no motivation for a shift, because the exposure conditions do not make the S uncomfortable and he gets little feedback even through locomotion. It was studies such as this one and those that follow which seem to leave the active-passive question still open. Hochberg (1963) noted that the verdict was still out at that time. It may be that movement is a sufficient but not a necessary condition for adaptation.

Held, Efstathiou and Greene (1966) attempted to strengthen the case for the importance of active, self-directed movement and consequent reafferent input. They noted that research on delayed feedback in other areas of psychology indicated that unless Ss adopted an appropriate cognitive strategy (i.e. move and then wait), they soon lost sensorimotor control. They hypothesized that if delay of visual feedback was introduced during exposure to wedge prisms, the nervous system would not be able to make adequate use of reafference to develop new afferent-reafferent pairings.

Therefore the degree of adaptation would be reduced. The experimenters introduced various levels of delay from three-tenths to three and three-tenths seconds. The results confirmed their beliefs, indicating that any level within the range they employed eliminated the adaptive shift produceable with no delay. The duration of delay produced no differential effects. While this does not provide definite proof of the necessity of active, self-directed movement, it does demonstrate the relevance of immediate informational feedback. The authors still must examine delays below three-tenths of one second, however.

Held and his associates stimulated both opposition and supportive research, which has livened up the study of adaptation. Templeton, Howard and Lowman (1966) and Singer and Day (1966) have attacked Held on the basis of a dissimilarity between his exposure and testing phases in the hand adaptation paradigm of Held and Gottlieb (1958), for example. Templeton et al. (1966) noted that simply looking at ones' hand beneath the optics provides a discrepancy between visual and kinesthetic information, but Held never provided any instruction to use this information. This they call "continuous display training with no task (p. 140)." Templeton et al (1966) feel this is too weak a task to demonstrate adaptation without reafference, if it exists. In their experiment, they proposed instead a task which involved the same movements in exposure and testing. The S's arm was strapped to a pivoting board. During exposure his arm was

moved by a motor. He informed the E when his index finger was uncovered and he was given knowledge of results. During pre and post tests pointings were made actively without knowledge of results. The authors found a significant shift due to displacement adaptation. They concluded that training procedures could produce adaptation without reafference when they forced Ss to use the information available (i.e. reduction of errors over trials during exposure) on the nature of distortion. These investigators did admit that only instructions were used to control passivity.

Singer and Day (1966) tried different combinations of activity and passivity across pre and post tests and the exposure conditions. They employed a displacing prism and a dependent variable of marking the location of two points etched on the apparatus above the prism. In the so-called passive condition Ss moved one hand with the other via a rotary control. This procedure obviously poses some difficulty, unless activity is conceptualized as a local process, rather than as a function of the entire organism. In a second attempt, active Ss moved their hands from side to side during exposure, and E did the moving during the passive phase. There were no differences between active and passive Ss in either experiment. The aftereffects were smaller than in the first experiment and the authors felt it was the result of spatial dissimilarity between the test and exposure conditions. On the active-passive question these authors seem to have accepted the null hypothesis that there were no differences.

Fishkin (1968) was impressed by the work of Singer and Day (1966) and decided to do his dissertation in displacement adaptation. Fishkin (1968), however, attempted to add to the body of knowledge by introducing several other variables besides that of the active-passive question. These included exposure duration and delay duration, the latter defined as the period of time between exposure and the post tests. Like Singer and Day (1966) this investigator tried to keep exposure and testing as similar as possible. S's arm was strapped to a board mounted on two rails which allowed five and one-half inches of lateral motion. During exposure Ss moved their hands back and forth or E moved their hands for them. The dependent variables were pointing to a target or positioning the hand so that it appeared directly in front of the S. The investigator found no significant difference between active and passive exposure, placing him in the same position as Singer and Day (1966) of accepting the null hypothesis. The exposure duration factor was not significant either, but displacement adaptation occurs rather rapidly anyway. One notable contribution was the significance of delay duration. A linear trend appeared for delays of 20 to 60 seconds. As the delay increased, the magnitude of the effects decreased. The author noted that for the two shorter delays the active condition was favored slightly while for the longer 60 second level the passive condition was slightly superior. There were no activity-delay interaction of significance; this may be an indicator for future research and there is no doubt that

delay must be controlled.

Weinstein, Sersen, Fisher and Weisinger (1964) asked the major question of this section directly, "Is reafference necessary for visual adaptation? (p. 641)." These authors noted that in Held's work it was questionable whether active and passive Ss were operating on the same level of visual activity and vigilance. Active Ss had to attend more closely on experiments requiring bodily locomotion to avoid stumbling. Furthermore, the active Ss had to make decisions not required of passive Ss, like which way to turn. In one experiment these investigators looked at the roles of decision making and self-induced movement. They employed 48 Ss. Ss were seated in a rotatable chair located within a large cylinder. The inside surface was covered with a white cloth upon which was a single vertical line. S's task in this cylinder was to align his body to the vertical line, with and without 13 diopter wedge prisms. This device served only for pre and post testing. During exposure Ss sat in a wheel chair while wearing prisms and were randomly assigned to one of four groups; passive, S was wheeled about and had no other task; move only, S moved the wheels but E steered; move and direct, S provided movement and direction; direct only, E pushed and steered according to S's directions. The pre-post test factor was significant ($p < .01$) but did not interact with the groups factor. This meant that all of the groups adapted. There were not any significant differences across the four group levels although the passive condition showed the smallest pre-post shift.

This was contrary to the authors' prediction that the two decision making groups would adapt to a greater degree. The range of shifts was very small, especially for a displacement study, $.72^{\circ}$ to 1.09° . All groups did show positive significant shifts. These results seem to contradict the necessity of self-induced movement as noted by Held. However, to conclude that no active-passive difference exists would be committing the error of accepting the null hypothesis.

In a second experiment Weinstein et al (1964) used 17 SS. In the pre and post tests S had to orient himself to a line, but E provided the movement of the chair. Exposure was done in the cylinder after pretests. S was repeatedly required to accomplish the same task while wearing prisms except that after each trial E told S he would set the chair to true zero, which was defined by the researchers as the mean of eight pretest trials without prisms. This was information feedback to allow SS to correct previous errors. After one-half hour a significant shift ($p < .05$) appeared. The authors stated that with no self-induced movement adaptation had occurred to an average degree, 14.3%, that was higher in one-half hour than Held and Bossom in 1961 had found in one hour, 11.4%. The authors believe that information feedback is the key to adaptation. Primarily, what they have shown, however, is that information feedback is another possibility as a sufficient condition. That it is a necessary condition would be challenged by Held and Hein (1958) where adaptation was demonstrated without knowledge of results. It is also possible

that information comes through many sources, one of which Held and Hein (1958) failed to control.

A note of compromise was sounded by Stanley Coren (1966), who recognized the question between Held and Hein (1958) and Weinstein et al (1964). Coren used two groups of Ss, twelve in all. They were exposed to a 25 diopter wedge prism. In the high information group, Ss pointed freely to a target and could see their errors. In the low information group, the S's hand could only move laterally on a track and therefore Ss could just ease on to the target and make no errors at all. Both groups produced post shifts which were significant from zero ($p < .02$) and the high information group produced effects significantly greater ($p < .02$) than the low information group. Due to the small sample Coren (1966) used the nonparametric Mann-Whitney U Test. This experiment could bear replication possibly as part of an attempt to explore additional variables. Coren (1966) concluded that because the low information group did adapt, reafference could have played a role. The fact that the high information group adapted to a greater degree indicated that perhaps reafference and other available information are used by Ss during adaptation.

Stimulated in part by Held, Ebenholtz (1966, 1968) became interested in optical rotation. He attempted to do what Fishkin (1968) had tried for displacement, examine new variables and their functional relationships. Ebenholtz accepted Held's (1961) thesis on the necessity of self-pro-

duced movement and coincident reafferent feedback. He therefore encouraged activity in his SS during exposure. Ebenholtz (1966) applied a three factor design to examine variables concerned with adaptation to rotation. These factors included exposure time (10 - 120 min.), degree of tilt (10° , 20° , 32°) and an eye factor which involved the effects of exposure on exposed and unexposed eyes to assess the degree of interocular transfer. Exposure time was not significant. This may have been a function of reaching the asymptote very early. Both the tilt (\bar{x} s of 3.5° , 5.59° , and 8.24° for exposed eye) and the eye factors were significant. Although there was no eye by tilt interaction, the author computed the ratio of the shifts from exposed to unexposed eyes at each tilt level. For 10° , 20° and 32° respectively, these were .41, .66, and .64. This indicated that there was interocular transfer although incomplete. The procedure of always post testing the exposed eye first may have reduced these ratios. Ebenholtz noted that even if the rate of adaptation for the first were maintained, it would take 38.6, 46.2, and 81.7 hours of continuous exposure for the three levels of tilt to reach completion, where adaptation equals the amount of optical rotation.

Ebenholtz (1966, 1968) proposed a theory for the rate of adaptation in terms of Held's (1961) comparator mechanism. He noted that both he in 1966 and Mikaelian and Held (1964) had found that adaptation was a negatively accelerated function of exposure time. Two major hypotheses are available as to the nature of the effective optical stimulus. It either

depends on the localized state of adaptation of the retina (dependence hypothesis) or it does not (independence hypothesis). In the former case the effective optical stimulus would be the angular difference between the level of adaptation of the eye and the current prism tilt. As adaptation proceeds, the angle moves toward zero. The second possibility, which Ebenholtz (1968) sponsors, is that effective tilt is independent of the status of the eye. Rather tilt as such is defined by the angular flow of the retinal pattern as the S's head moves. The effective optical stimulus is the difference between two successive flow patterns. What this refers to is a change in the way images move across the retina as the optical situation is altered. S has become accustomed to accounting for changes in the retinal array as a result of his own movement. When he is exposed to prisms for the first time or changed from one set to which he has adapted to another, the flow pattern on the retina is altered. The analyzing of these differences is done by the comparator, which compares present tilt against traces of previous input. This mechanism becomes less efficient over time, providing the negatively accelerated time function for adaptation. This is but one reference in many to the concept of a storage mechanism. It seems to be of a more short term nature than those of Kohler (1964) or Rock (1966).

The major technique used by Ebenholtz (1968) to test his theory was to manipulate the magnitude of optical distortion according to the S's level of adaptation, defined as the

average number of degrees that S sets a rod from the vertical after exposure. Suppose S adapts for a given period of time and demonstrates a level of adaptation of x degrees; there are two hypotheses that could be used to explain what would happen if the optical system were changed from its original setting of say 30 degrees to a new setting of x degrees, which is less than 30 degrees. The dependence hypothesis, which Ebenholtz does not accept, would say that the effective stimulus which S uses is the difference between the given level of S's adaptation and the optical rotation. If they both equal x degrees, the effective stimulus is zero and the level of adaptation should remain constant. The independence hypothesis would state that since a change in optical rotation from 30 degrees to x degrees was imposed, a change in retinal flows was also introduced. This should lead to a change in the level of the organism's adaptation. In Ebenholtz's (1968) study ss were exposed to 30 degrees rotation for one-half hour. Their level of adaptation was measured with a rod alignment task and determined to be 8.3° . The optical system was then set at this level, a change downward of about 22° . After an additional one-half hour exposure, a decrement in level of adaptation appeared. This was as predicted by Ebenholtz's (1968) independence hypothesis.

The author admits that there may be more parsimonious explanations of his data, such as ss responding to each tilt independent of other tilts. The vertical meridians of the eyes would serve as a base line for measuring effective optical

rotation. This sounds a little like Rock (1966), but Ebenholtz dismisses it as untenable in the face of his evidence. In another study, Ebenholtz and Mayer (1968) compared two groups of eight ss each. One was exposed for one-half hour to 30 degree rotation while the other began with a five degree tilt which was increased in five degree increments every five minutes. After exposure both groups had equivalent levels of adaptation of 6.5° . The time function slope of the two groups differed, however, being shallower for the first group. Ebenholtz and Mayer (1968) used the comparator model to account for this. The change for the first group from no prism to a 30 degree tilt was the greatest and provided a more rapid reduction in the effectiveness of the comparator mechanism.

Much of Held's work and that of his followers has been based on the postulation of various constructs like the comparator. Throughout this literature one gets the feeling that these authors want to specify a neurological locus for the mechanisms but refrain from doing so for lack of information. One can not doubt that this work has been immensely productive; but, by their hesitance, these investigators implicitly admit that perhaps even today we are not quite ready for a purely physiological approach to adaptation. Gibson (1937) stated this explicitly. The theory will no doubt come with time and research at both neurological and global perceptual levels. This leads to another question in the field: What is the nature of the adaptive shift?

Obviously Held, his co-workers, and followers would

seek some central nervous system locus for adaptation. As to the nature of this perceptual change, they referred to a change in the correlations between efferent output and reafferent feedback. This bears a strong similarity to Stratton (1896, 1897) who referred to a change in harmony between touch and vision, but he did not stress the importance of activity for this relationship. Rierdan and Wapner (1966) referred to an alteration in the relationship between object perception and body perception. Rock (1966) felt the shift occurred within a trace system as the result of a discrepancy between egocentric vertical and spatial vertical or egocentric direction and the direction of external space. Rock (1966) accepted that the majority of change in adaptation involved a visual-phenomenological shift. All these approaches stressing vision and/or some form of a relationship postulate a memory or storage mechanism which initially tells the observer how things used to be but gradually learns how things are.

In contrast with these approaches is the proprioceptive theory of Charles Harris (1963, 1965). While not taking a strong stand on the active-passive question, Harris (1963) felt that since the perceived position of a body part was dependent on information from joint receptors and not on the movements required to get there, it would not matter whether a hand was moved actively or passively for adaptation to occur. Harris (1963, 1965) defined the locus of adaptation as a change in the "felt position" of body parts resulting from a shift in the information supplied by the proprioceptors in the joints.

The research that this theory grew out of was initially concerned with hand viewing through displacing prisms. Harris (1965) noted that when as S wore such prisms, the position of his hand as determined by internal sensors was discrepant from that determined by vision. It is the position estimate determined by internal sensors which changes toward the non-veridical and toward agreement with vision. The investigator cited his own research in which he found no intermanual transfer of adaptation when ss' heads were immobilized. This result would obviously be predicted from the theory which essentially postulates a change somewhere below the central nervous system level. Hamilton (1964) confirmed the necessity for head movement for intermanual transfer of displacement adaptation. When head movement was required, a significant amount of transfer occurred. Hamilton (1964) therefore accepted the proprioceptive theory and explained Helmholtz's (1925) results, where he obtained intermanual transfer, as the result of uncontrolled movement.

Harris (1965) attempted to extend his theory to more global conditions in which ss were allowed free locomotion while wearing prisms. This attempt was overextended but essential if the theory was to handle such results as those of Stratton (1896, 1897) and Kohler (1964). Harris assumed that all global adaptation was still a function of proprioception but that the felt position of the head on the neck and on occasion the felt position of gravity had changed. Harris (1965) believed adaptation occurred in stages from the hands,

to the arms, and on to the shoulders and body. He concluded that vision was inflexible and that visual perception was a given at birth. This seems like an unjustifiable belief at best. It is probably folly to explain all adaptation on the basis of one mechanism. The various types of distortion probably have different informational bases, displacement no doubt requiring the least amount of information for a shift to appear. This is evidenced in part by the rapidity of changes with displacement in contrast to the longer periods required by rotation and inversion. A modification of Harris's theory, which does not speak precisely to this point, does offer a compromise between rigid proprioceptive theory and the larger body of theoretical attempts which propose storage mechanisms and relational changes (Pick & Hay, 1964; Hay & Pick, 1966).

These researchers stated that the traditional type of eye-hand coordination tasks do not provide an answer as to whether adaptation occurs in one or the other or in the relationship between the two. Hay and Pick (1966) wondered whether vision always compelled changes in other modalities or if it ever changed itself. In their first experiment eight SS were exposed for six weeks to wedge prisms. Eye-hand coordination was measured on a Held and Gottlieb (1958) type task of marking the virtual locations of targets. Ear-hand coordination was assessed as was eye-hand coordination before, during and after exposure. Blindfolded SS had to mark where they heard a clicker. The eye-hand shift during exposure went to near completion, almost matching the amount of distortion, while

the ear-hand shift occurred only for the first day; then a reverse shift occurred. In other words, there was no evidence of adaptation from the first day to day 20 on which ss demonstrated pre-exposure level ear-hand coordination. If adaptation was purely a proprioceptive change in the hand, this would not have occurred. After day 20 a negative shift appeared which the authors noted was unexplainable on the basis of any theory. The authors postulated that two processes of adaptation were occurring successively. Initially, adaptation involves proprioceptive changes. A corresponding visual or auditory shift develops more slowly, eventually allowing the early proprioceptive alterations to dissipate. In alternate experiments other coordination tests were employed, providing measures of eye-hand, ear-hand, eye-head and ear-head coordination. Earlier results were replicated except that there was not a resurgence of shift for the ear-hand relationship which showed greatest adaptation initially and then declined during exposure to a stable point half that of the initial. Shifts in ear-eye and eye-head coordination validated that some visual change was taking place, a fact that Harris (1965) could not have predicted.

Hay and Pick (1966) concluded that both proprioceptive and visual changes do occur. The latter change involves allowing many nonvisual stimuli to conflict with those processed through vision. This can be accomplished, for example, by providing ss with a view of their own body. This permits a conflict between visual information and proprioceptive feed-

back. Nonvisual stimuli can also include those processed by audition. The results of these researchers seem to be supported by their well-designed experiments. The possibilities for further research are many and the implication could help bridge the gap between visual and motor theories.

Held and his co-workers have tried to confront the proprioceptive theorists with an approach that attempts to take their results under consideration (Efsthathiou, Bauer, Greene, and Held, 1967). In their research program these investigators varied the nature of the target reached for or marked in the pre-post tests. They followed a paradigm of testing similar to that of Held and Gottlieb (1958). They found a significant difference between a task where S marked the virtual location of four target points and when S was required to place his exposure hand above that point on a surface below which was his unexposed or contralateral hand. In the latter task Ss were blindfolded in both pre and post task. If a change in the felt position of the exposed hand accounted for the adaptive shift, a difference between the two tasks would not have been predicted. Efsthathiou et al (1967) felt that the eye-hand relationship (the afferent-reafferent correlation) had changed only for the exposed hand. The felt position of both hands, however, remains the same. This, in fact, they felt may actually limit the magnitude of an adaptive shift. To support this, they proceeded to show to their satisfaction that the felt position of body parts does not change. They trained a limited number of Ss

to localize four pins on a surface while blindfolded. They used this ability in the pre and post tests around a three minute exposure period. This seems like an extremely short exposure period in a design where a rejection of the null hypothesis was not expected. That no adaptive shift occurred was not surprising. Although they have not modified the basic theory markedly, this approach did represent an attempt to deal with the work of Harris (1965) and others. It was far from conclusive, however.

Up to this point most of the literature cited has been motor oriented in nature. A position which deemphasizes these aspects and supports a more visual, phenomenological, and information processing theory is that of Irving Rock (1966). Rock has arrived at a nonreductionist consideration of adaptation, which has had a considerable effect on this writer. Rock (1966) noted that adaptation research was important because it allowed an examination of perception as a process undergoing change. Like many of his predecessors he has found it necessary to utilize the concept of a storage mechanism in his thinking. An observer notes that something is wrong when he examines the world through distorting optics. He does this whether he can touch objects or not. Therefore the discrepancy is not between vision and touch but within the visual system itself. According to this theory, man has developed a complex trace system which stores how stimuli were oriented on the retina. The egocentric orientation of an individual resulting from previous

experience is a direct function of how stimuli impinge on the retina and of no other visual cues. When optics distort an S's vision, what he sees is contradictory to his normal egocentric trace system. Adaptation involves the building of new traces through the use of available stimulus information.

This information comes from many sources. Both Rock (1966) and Mack (1966) indicated that Ss have to be familiar with available stimulus objects for adaptation to occur. They can not know if an object is disoriented if they have never seen it before. Memory carries traces of objects seen under normal conditions. These stimulus copies may be compared with present transformed proximal stimuli and from this comparison the nature of the distortion can be deduced. Another source of possible information is the sight of a body part within the stimulus field. This makes it very difficult for a "separation of system" to occur (Rock, 1966). In other words, when S sees a part of himself in the field, it is more difficult to tune out or ignore the information available than it would be if he could accept his body as being part of a different stimulus system. It might be simpler to avoid contradictory information than to utilize it in some cases. A case in point is the rod-frame task in which Ss can obtain the visual reassurance that their bodies are in a normal orientation even though the field is tilted. A third source of information is movement. Unlike Held and his co-workers this was not seen by Rock (1966) as an essen-

tial condition nor must the movement be self-produced and directed. Weinstein et al (1964) obtained adaptation with non-self-directed movement. Mack (1967) found that passively transported Ss adapted as long as they knew the nature of the movement. Movement is informative for visual adaptation because it provides a different retinal flow than S would expect on the basis of previous experience (Mack, 1967). For example in adaptation to rotation, an S without lenses told to follow a line on the floor or pushed around on the line has a right to expect that by keeping a given retinal orientation of the line, he will remain on it. If, however, prisms rotate the proximal stimuli, then to stay on the line a new retinal orientation is necessary. He must continually veer to the right or left to remain on target. S must know he is moving and the nature of the movement so that he can discount those retinal changes that would accrue from movement, leaving the discrepancies to which he must adapt. Each source of information is sufficient alone although not an essential condition for adaptation. The adaptive process involves the building of a new trace system where egocentric orientation is altered. Meaning is developed through experience and the trace system at any point in time contributes information to any phenomenal experience which goes beyond the relative aspects of the immediate proximal stimuli (Rock, 1966). Mack (1966) and Rock (1966) noted that perceivers use information although they may often be unaware of how it affects their perceptions. This idea is very similar to those presented

by Gibson (1966), where he emphasized the amount of information processing that occurs without the individual being aware of specific sensations.

Evidence on this theoretical approach suffers from the same deficiencies as that of other approaches treated earlier. Most samples are small; stimulus control is poor; and the acceptance of the lack of a significant difference as a positive finding is seen again. An example of this third problem was apparent in Mack (1967). In an effort to show that movement was not necessary for tilt adaptation, she obtained data from sixteen SS who participated across active and passive conditions in a repeated measures design (counter-balanced for order). Both the active and passive levels showed a significant shift of the same magnitude. It seems that if an investigator does predict a lack of difference, he can at least build enough power into his design to find it if it exists.

Rock and Mack spent a great amount of time attempting to deal with the Gibson effect, a phenomena which Gibson (1964) himself apparently no longer took seriously. Mack (1966) in her dissertation had ten SS stare for one-half hour at a tilted cardboard circle with some lines inscribed on it. There were no aftereffects, so for that study she concluded that the Gibson effect was not a confounding factor. Mack and Rock (1968) attempted to control for the Gibson effect by only exposing SS when their heads were in the horizontal plane. Apparently disrupting the vestibular feedback was supposed

to inhibit the formation of the local Gibson affect, which might have confounded the results of higher level adaptation. Obviously these authors did not read Gibson (1937) or Kohler (1964) very carefully. The existence of the situational after-effect makes the probability of a local normalization process, with respect to prismatic rotation, a very improbable event.

Mack (1966) and Mack and Rock (1968) attempted to demonstrate that there was more to adaptation than getting used to an atypical body posture, an idea proposed by Alan Hein in 1965. Mack and Rock (1968) asked Ss without prisms to remain with their heads tilted or to examine their feet, which were turned in one direction or the other. There were no significant shifts for the group as a whole, but again the sample was small and individuals varied between 0° and 3.75° . In the same experiment Mack and Rock (1968) tried to support their overall theory by showing that information provided by movement was not essential if information could be provided from other sources. If Ss could see their entire bodies in the field, the authors felt that the information would be adequate. A relatively large sample of 59 Ss was used. Ss examined their own mirror images through rotating prisms. The researchers were forced to conclude that sight of one's body was not a reliable precondition for adaptation. They further concluded that the most consistently effective information was provided through movement. This was by no means an acquiescence to reafference theory, because movement was not required to be active or self-directed. This did represent some modification of the

earlier theory of Rock (1966). Mack and Rock (1968) completed their article by stating that adaptation is often incomplete, because man must form a compromise between the old trace system and the new meaning given to egocentric orientation by adaptation.

An interesting study was designed by Quinlan (1970) to assess the importance of viewing body parts during exposure. He coupled a three level sight of body factor (all, hand, none) with a two level activity variable. The latter involved active walking versus being wheeled about on a small platform. This gave the experiment a potential for not only examining main effects but also interactions, which might have been obtained. Exposure involved a 15 degree rotation provided by a mirror system. Three dependent variables were used: apparent vertical, aligning a luminous rod to gravitational vertical; apparent body position, aligning the rod to the body; and tactual-kinesthetic, aligning a board with the palm while the eyes were closed. The results indicated that the two visual dependent variables were not significantly different from each other across the three levels of body viewing. The E felt justified in pooling his data from these two variables. It was found that the active group had significantly larger shifts than the passive locomotion group. The body viewing factor was also significant, while there was no view by activity interaction. Post testing indicated that while the all and no view levels were different, the hand condition was not different from either of the two. Quinlan

(1970) concluded that information from active walking and from sight of the entire body enhanced adaptation. The latter is in contrast to Mack and Rock (1968) who perhaps did not provide for enough retinal change through motion to enhance their effects. Restriction of head movement, Quinlan (1970) believed, may have been one reason why Mack (1967) did not find an active-passive difference. He noted that his passive, all-view Ss showed similar shifts to his active no-view group. Passive Ss could move their heads, however, which when viewing their bodies produced reafference and/or movement information to the retina. Quinlan (1970) then was a follower of the reafference hypothesis. He concluded by noting that the failure of his tactual kinesthetic variable to produce shifts while the visual tasks were successful indicated the visually localized nature of the adaptive process.

It is apparent that conclusive research in adaptation theory is still lacking. Both motor and non-motor information offer productive lines of investigation. Similarities include a resounding reference to storage mechanisms and considerable interest in the importance of activity. Many controversies are more semantic than physical and hopefully someday a common labeling system in the area will be devised. One trend, however, which is glaringly apparent across most of the research is a lack of interest in the stimulus conditions during exposure.

To the extent that stimulus information is relevant to the adaptive process, what the organism sees through his

prisms can not be ignored. Wohlwill (1966) stated that one problem with Harris' (1963) proprioceptive approach was that it could not explain why with the same amount of movement, adaptation would be greater in a building corridor than in an open field, where information about the nature of the distortion is more limited. Various allusions to the importance of the field have been made, with very little effort to follow them up. Kohler (1964) noted that certain stimuli were adapted to more quickly than others. Rock (1966) and Mack (1966) felt that the key might be the familiarity of certain objects which could provide more information on the nature of the distortion. Held and Rekosh (1963) and Mikaelian and Held (1964) attempted stimulus control by minimizing the available patterned stimuli. In both cases adaptation after-effects occurred, but with a large reduction in magnitude. Mortant and Beller (1965) took a novel approach in examining the effects of observing lines through prisms contrasted with those of observing objects. This was done in relation to two levels of activity, walking and sitting, and two levels of tilt, 15 degrees and 75 degrees. It was hypothesized that for lines, adaptation would be towards the nearest major axis (i.e. vertical for 15 degree tilt and horizontal for 75 degree tilt) while for objects all adaptation would be towards a righting of the field regardless of tilt. These results were confirmed. Furthermore, walking enhanced the effects with objects but not with lines. The investigators felt that this was due to more meaningfulness for objects which have a history of preferred

positions. Lines, being more abstract, have no such meaning.

Other work on the relevance of the field can be drawn from the old field dependence research of Witkin et al. (1954). Striving to develop a relationship between personality and perception, these psychologists did a series of studies based on work done by Ash and Witkin (1948a, 1948b) and Witkin and Ash (1948a, 1948b). These investigators were concerned with how various fields affected perception of the vertical and to what degree an individual possessed an unmodifiable perceptual style. This style was supposed to provide Ss with a constant degree of dependence on the field regardless of its nature. Inadvertantly, however, the Es found that certain fields were more effective in distorting the perception of the vertical than others. The basic task in all the experiments was for S to align a rod, the field or himself with true gravitational vertical after having been exposed to a tilted field for a given time period. Three major types of fields were used over a period of years; a square luminous frame, a room with one side missing that S examined from without, and a room within which S was placed and could be rotated independently of S. This latter condition was considered by Rock (1966) as most analogous to prismatic adaptation with one basic difference. In all of Witkin et al.'s (1954) work S could always look down at his body which was not tilted and this could have allowed for a "separation of system", a distinction between his seen body and the field. The effect of Witkin et al.'s three fields were notable in that from the square to the com-

plete room they increased in magnitude, leading one to believe that the structure of the field is an important factor worthy of further investigation.

Another study which indicated differential effects resulting from the specific nature of the field was my masters research (Stein, 1970). In this research I employed a three factor design with repeated measures on the last two. The first factor, using independent measures, was sex difference. The experiment involved 40 males and 40 females. They were exposed to two stimulus variables. The first, referred to as line articulation, concerned three stimuli (random form, parallel lines, square) with an increasing number of horizontal and vertical lines from the random form to the square. The second stimulus variable, known as projection articulation, involved a three dimension-like projection of these objects, which provided three additional stimulus fields (three dimensional random form, parallel planes, and a cube). The order of field presentation to each S was randomized. All Ss were exposed to a rod alone and required to align it to the vertical before and after the series of six field stimuli. After viewing each field for three minutes, S was asked to do the same task with the rod placed within the field. The major question was the level of field specificity in determining the subjective vertical. While Witkin et al. (1954) had accepted that perception of the vertical was primarily a function of the observer, I hypothesized that the structure of the field was important. The results supported my conclusions. The field

that produced the most error in perceiving the vertical was the cube. This was followed by the square and then the parallel planes. The three dimension-like random form produced an error significant ($p < .01$) from the rod alone while the two dimensional random form did not. A significant interaction ($p < .001$) between the two stimulus variables, line and projection articulation, made it necessary to specify levels of each before discussing differences in the other. The sex difference did not appear. The results indicated that if perceptual style was a factor in perceiving the vertical as Witkin et al. (1954) proposed, then this style must be quite flexible according to the nature of the stimulus field.

The Research Question

Most prism exposure in the past has involved SS walking or sitting in a relatively free environment. The importance of stimulus familiarity is certainly worth looking at, but as a first step in a research program a simpler question was asked. What would the effects be if the stimulus fields during exposure were limited to a specified few and to only one for any given S? To accomplish this, a qualitative variable of stimulus information was thought adequate. Stimuli were selected on the basis of their possible relevance for future research.

Much controversy has been generated by the active-passive question. Research has almost invariably been divided into two levels, which are probably falsely dichotomous. An alternative was to add another level of activity in order to

probe the possible importance of eye movements. In previous passive conditions, no one has ever controlled eye movements in any way. This leads to a third possible question. Would there be any interaction between a multilevel activity factor and a corresponding multilevel fields factor? Previous research has not considered this. A fourth question concerned the importance of seeing part of one's body in the rotated prism field. This could qualify the effect of other stimulus variables.

Design and Hypothesis

The first design was used as an important control. It involved one group of Ss who were exposed actively to a cube with no rotation provided. This group was compared with the analogous group which was exposed to rotation. A two by two design was required. The first variable, A, was rotation versus lack of rotation. The second, B, was the pre-post testing. The purposes of this experiment were to discover if rotation had any effect relative to no rotation and whether the optical system produced any effects without rotation. It was essential that the pre-post condition without rotation show no shift while the comparable condition with rotation show a significant difference. Such effects were thus hypothesized.

In the second design a 3 x 5 x 2 factorial approach was employed. The three level activity variable involved a fixation condition where Ss were instructed to fixate the midpoint of the stimulus field, a paced eye movement condition

in which they were required to follow a point of light around the front contours of each stimulus, and finally an active tracing procedure where Ss traced the front contours of the stimuli with their dominant hands. Independent measures were obtained across all the levels of the activity factor and the field factor. Furthermore, to avoid confounding by the sight of a body part in the last level of activity, Ss were required to see part of their dominant hands within the field at the other two levels, although they were not allowed to move them.

The second factor was referred to as the field variable. It included five stimuli; circle, random form, three dimensional random form, square and cube. These stimuli contained a diverse number of lines, angles, upright and horizontal lines, and right angles. The three dimensional random form contained the most lines and angles while the cube had more horizontal and vertical lines and more right angles. The third factor was simply the pre and post testing which was to indicate the presence or absence of adaptive shifts.

The majority of this work was based on speculative hypotheses since there was little relevant background data available. Therefore, it was believed that all main effects and interactions were empirical possibilities. If differential adaptation effects occurred across the activity or field variables, it was thought that interactions with the pre-post variable would be probable. This was due to the fact that differences due to either the activity or field factors in the pretest would be the result of only what different Ss brought

with them to the experiment. Treatment variance could not have appeared until the post test after Ss had been exposed to optical rotation. It was further hypothesized that in the activity factor the active trace position would be superior to the passive fixation condition. It was felt that the eye-face condition would be somewhere in between. In the field factor, it was felt that to the extent that adaptation research mirrored the field work of Witkin et al. (1954) and Stein (1970), the stimuli should show some differential effects. This meant that the cube and square would produce the highest amount of error from true vertical and the circle and random forms the least error.

In the third design, the importance of the sight of the hand was examined. A 2 x 2 x 2 three factor design was used. The sight of body factor consisted of sight of hand vs no sight of hand. The field factor employed the circle and the cube as levels of stimulus information. The third factor was the familiar pre test, post test arrangement. Exposure was accomplished with Ss fixating the midpoint of the stimulus. It was noted in the introduction that with sight of the whole body Mack and Rock (1968) found an unreliable relationship. Quinlan (1970), however, did find sight of body effects. Interaction of the pre-post testing factor with the sight of body and field factors was hypothesized. A pre-post shift should not appear when S could not see his hand but viewed the circle stimulus. A shift using the circle and view of hand would indicate the importance of the latter. A shift with the cube alone

would indicate a high source of information while a shift using the cube and view of hand would include effects of both body part and field information.

The fourth design involved a different dependent variable. The question was whether a measurement technique that had motor components would be as effective as the exclusively visual technique. To the extent that E could be technically precise, it was felt that this might shed some light on the visual-proprioceptive controversy. The dependent variable task involved having Ss point directly in front of them from the stimulus fixation point. From a scale beyond their reach, E could read their errors in degrees from their true front. The data were collected from Ss in the active level of the second experiment. A five by two design was employed. The five level factor contained the same stimulus fields as in design 2. The two level variable was the measures factor. Indication from pilot data were that this new visual-motor dependent variable would operate differently and less reliably than the visual variable.

The fifth design was again concerned with the visual-motor dependent variable. The purpose of this design was to examine whether different results for the visual-motor dependent variable would obtain when Ss pointed with eyes closed. In design four Ss had been able to observe their pointing responses. Exposure was of the active-trace nature and the data produced was compared with the data from the group in design two which was in the active-trace-cube condition and did the

pointing with eyes open. A two by two design was proposed. The first factor involved the eyes open--eyes closed variable. The second was again the measures factor. While a difference in the first factor was considered a possibility, no firm hypothesis was ventured.

METHOD

Subjects

Eight people were randomly assigned to each of 19 groups in these experiments for a total of 152 ss. The sample consisted of 76 males and a corresponding number of females, ranging in age from 17 to 35 with a mean of 19.5. Most ss were required to participate in this or another experiment as part of their introductory course in psychology. An equal number of each sex was assigned to every cell in all designs. Each was required to have good eyesight, no worse than 20-30 without glasses. Forty-seven percent of the total wore glasses. Because of the demonstrated interdependency of visual and postural information, ss were asked if they had any history of inner ear infection, balance problems, or muscular and coordination disturbances, any of which could affect performance in an inconsistent manner.

Apparatus

The equipment in this experiment involved a new approach to adaptation and consisted of three main elements. The most important element was the optical system which rotated the visual image. Since no unit was available on a premanufactured basis, a prism system was ordered from and built by Hudson Precision Optical Company in Hudson, New Hampshire. Two prisms were cemented together and mounted in a rotatable cylinder. The prism unit was mounted approximately fifteen inches from the stimulus surface. The resulting field of vision s was permitted was limited to a circle, three inches in diameter. The optical

system also provided a right-left reversal similar to what would be produced by a mirror. This was corrected by a right angle prism mounted at one end of the unit, which reversed the image and provided the added advantage of bending the proximal stimuli ninety degrees, allowing the S to sit upright and look straight ahead at the stimulus presented on the horizontal surface near his lap.

The second element of equipment was a Lafayette Photo-electric Pursuit apparatus mounted beneath the horizontal surface upon which the stimuli were placed. The purpose of this machine was to present a point of light moving around the contours of the stimulus in order to meet the requirements of the eyepace level of activity. Figure 1 represents how the stimuli were set up above the pursuit unit. The distances are exaggerated for clarity. The stimulus, which Ss actually saw, was directly beneath the glass surface of the table. It consisted of a black line drawing on white translucent plexiglas. Between this stimulus and the pursuit unit was another sheet of clear plexiglas which had been painted flat black. The stimulus figure upon it had been etched out of the black surface and was directly in line with the stimulus above. Thus when the pursuit light rotated, the light was only allowed to pass through the etched part of the lower stimulus. This light then passed through the translucent plexiglas and appeared to Ss as a point of light moving around the contours of the black line drawing.

The equipment for measuring the two dependent variables comprised the third major element. In the back wall of the booth in which Ss were seated, as shown in Figure 2, was a

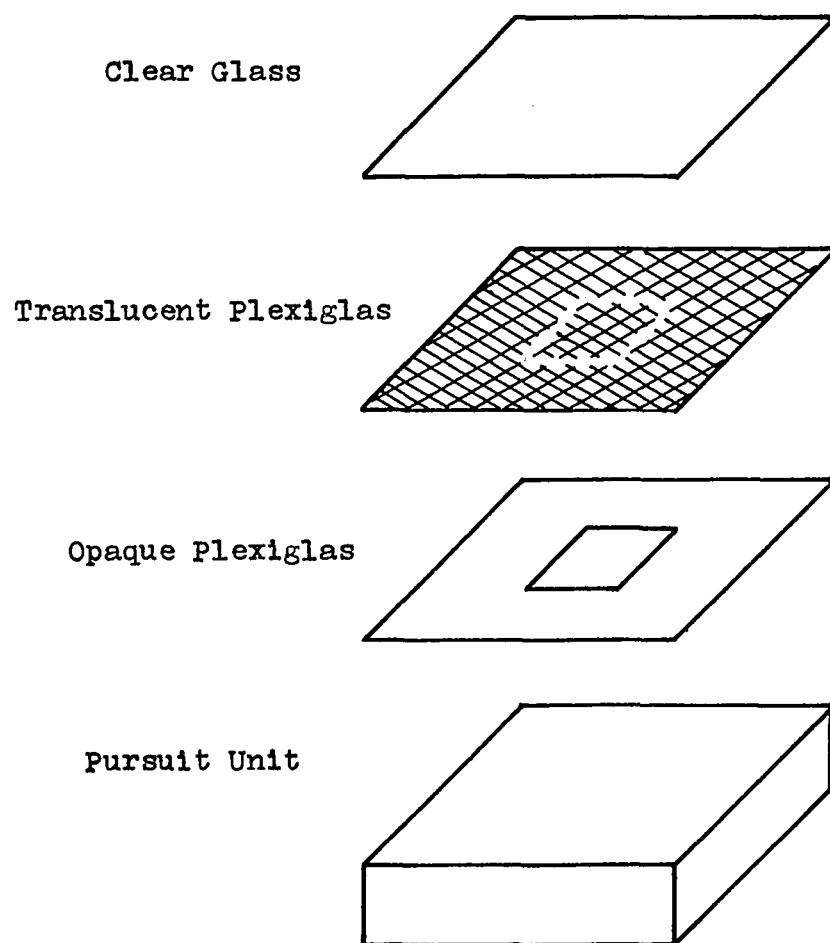


Fig. 1. Arrangement of fields above pursuit unit.

large circular hole. Behind this was a rotatable rod at each end of which was a small neon electric bulb. On the surface behind the rod was a protractor, the zero point calibrated to the gravitational vertical with a plumb bob. Ss' view was limited to the two points of light, which they attempted to align with their subjective estimate of the vertical. The measurement device for the visual motor variable was simply a large protractor taped to the glass directly in front of the S. It was not in his view. Black cloth was draped over the entrance to the stimuli, through which Ss placed their hands and forearms. The dominant hand and forearm were then rested on a skid which could slide around on the surface above the stimuli. The skid was simply a piece of plywood padded with foam and having sides to keep S's arm in place. Although Ss moved their hands in one condition only, all still wore this skid with the exception of the group in Design 3 who saw no part of their hands during exposure.

All elements of equipment were housed in one modular unit as indicated in Figure 2. This unit was painted in flat black on all sides exposed to Ss and the ceiling was pure white, approximately six feet and six inches from the floor. The unit had its own lighting system, consisting of three rheostatically-controlled sockets containing 100 watt soft-white bulbs. A deflector above the prism unit provided indirect illumination of the stimuli, thereby reducing glare and reflections.

Five stimulus fields were used in this experiment.

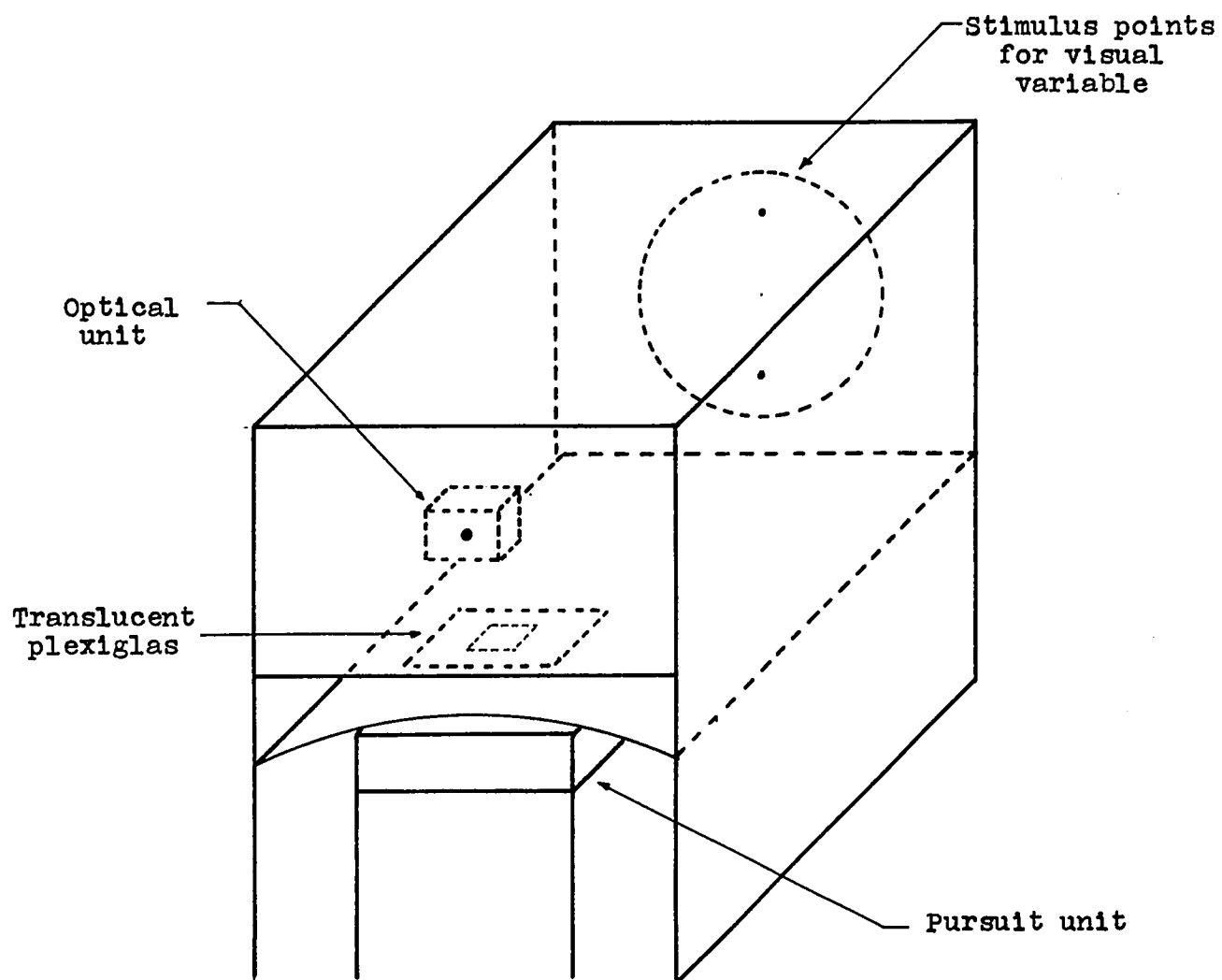


Fig. 2. The apparatus.

They appear in Figure 3, in actual size. Each S was exposed to only one of these stimuli outlined on translucent plexiglas beneath a glass table top as indicated in Figure 1.

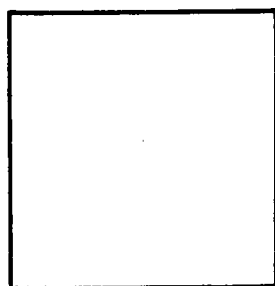
Procedure

Before entering the apparatus, various preliminary activities were carried out with each S. E filled out the data sheet with information obtained by questioning S as to his vision and the presence or absence of problems that might disqualify him. A routine eye test of eye dominance was performed, for each S was required to use his dominant hand and dominant eye. The test involved the following, E handed S a sheet of translucent plexiglas with a small hole in the center. He instructed:

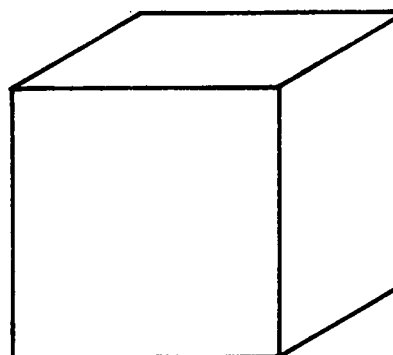
Hold this plexiglas loosely in front of you at waist level. When I say "Ready, now", lift the sheet to your nose and look through it while constantly looking at that point on the wall.

E indicated a prepared spot on the wall, then required S to follow the instructions twice. The dominant eye was defined as the one S used to fixate the prescribed point. Hand dominance was determined by asking the S which hand he usually preferred to use.

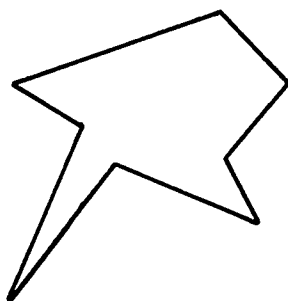
E then read the appropriate instructions to S, and upon completing them each S was seated before the apparatus at which time room illumination was turned off. The subject was made comfortable at the eyepiece of the module and a moveable chin rest was adjusted. For Design 1 S's dominant hand was placed in the apparatus and the other hand was placed



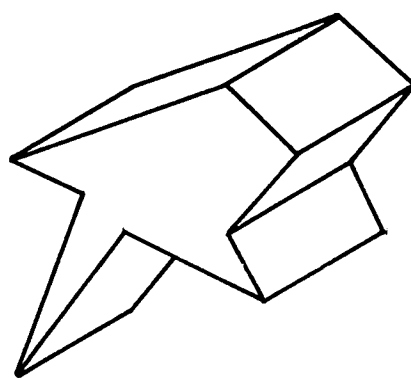
Square



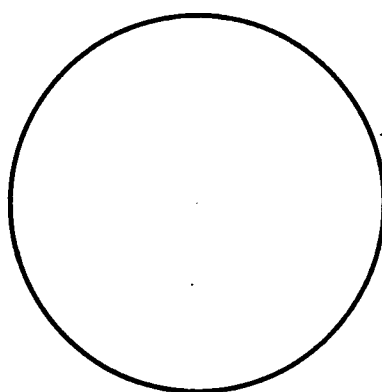
Cube



Random Form



Three Dimensional Random Form



Circle

Fig. 3. The stimuli (actual size).

in his lap. He was not able to see his hand until exposure but this was done to keep proprioception during testing and exposure as similar as possible. In Design 3 for the no-hand condition, Ss did not wear the skid and kept both hands in their laps. The instructions were repeated at appropriate times during the experiment.

Table 1 presents a schematic diagram of all five designs. The first three designs involve the visual point alignment task. The pre and post tests were taken before and after prism exposure. At no time were measures on the visual dependent variable made with the prisms in the field. Each S viewed the stimulus field for a period of fifteen minutes regulated by a stopwatch. Prism rotation was thirty degrees from the vertical in all designs. The direction of rotation was counterbalanced within each cell. Half of the males and half of the females in each field-activity combination were exposed to one direction of rotation while the other half received the opposite direction.

The first design involved two factors: rotation vs no rotation and the pre-post testing. One group of eight Ss were run under the prism rotation condition and the second group of eight Ss were run under the prism non-rotation condition. The first group received the four trial visual pretest, then actively traced for fifteen minutes the cube stimulus which was prismatically rotated thirty degrees. Following this, they accomplished four post test trials. The other group received the same experiences except that the stimulus field was not

TABLE 1
Schematic Designs

| <u>Design 1</u> | | |
|-----------------|----------------|------------------|
| <u>Factor</u> | <u>Level</u> | <u>Condition</u> |
| A | a ₁ | Rotation |
| | a ₂ | No Rotation |
| B | b ₁ | Pretest |
| | b ₂ | Post test |

| <u>Design 2</u> | | |
|-----------------|----------------|--------------------|
| <u>Factor</u> | <u>Level</u> | <u>Condition</u> |
| A | a ₁ | Passive Fixation |
| | a ₂ | Paced Eye Movement |
| | a ₃ | Active Tracing |
| B | b ₁ | Circle |
| | b ₂ | Random Form |
| | b ₃ | 3-d Random Form |
| | b ₄ | Square |
| | b ₅ | Cube |
| C | c ₁ | Pretest |
| | c ₂ | Post Test |

| <u>Design 3</u> | | |
|-----------------|----------------|------------------|
| <u>Factor</u> | <u>Level</u> | <u>Condition</u> |
| A | a ₁ | Circle |
| | a ₂ | Cube |
| B | b ₁ | View of Hand |
| | b ₂ | No View of Hand |
| C | c ₁ | Pretest |
| | c ₂ | Post test |

TABLE 1 (cont.)

| <u>Design 4</u> | | |
|-----------------|----------------|------------------|
| <u>Factor</u> | <u>Level</u> | <u>Condition</u> |
| A | a ₁ | Circle |
| | a ₂ | Random Form |
| | a ₃ | 3-d Random Form |
| | a ₄ | Square |
| | a ₅ | Cube |
| B | b ₁ | Pretest |
| | b ₂ | Post test |
| <u>Design 5</u> | | |
| <u>Factor</u> | <u>Level</u> | <u>Condition</u> |
| A | a ₁ | Eyes Open |
| | a ₂ | Eyes Closed |
| B | b ₁ | Pretest |
| | b ₂ | Post test |

rotated but maintained at a normal orientation. After completing the preliminary activities, Ss received the following instructions:

I am now going to explain the experiment to you. Then I will repeat the instructions as we go through it. The experiment consists of three parts (five parts--active condition). In the first part after you are seated and I turn out the laboratory lights, you will see two points of red light which I will be able to move clockwise or counterclockwise. Your task will be to tell me as I rotate them when you perceive the points to be vertical. By vertical, I mean, for example, parallel with the walls of the building. We will do this four times. Each time you tell me when the points are vertical, I will ask you to close your eyes while I reset them to a new starting position. After the fourth trial I will again ask you to close your eyes for a slightly longer period while I adjust the equipment. When you open your eyes, you will see before you your hand and an object which may look like this: (show card). If your hand is not in your field of vision, I will tell you how to move it so that you can see it. At this point the next part of the experiment begins.

The card mentioned in the instructions showed a picture of the appropriate stimulus. See Figure 3. While the instructions were read in entirety prior to S even sitting before the apparatus, it is clearer for explanatory reasons to now consider this as the second time through and the experiment is actually being conducted. When the preliminary instructions were repeated, the pretests were done with the visual point alignment task.

The rod was begun in a random position ranging from thirty to seventy degrees from the vertical. The direction of rotation was counterbalanced by alternating on each successive trial. The first three trials of the pretest were eliminated as practice and S's pretest score was actually the last score

he produced on the pretest.

When the pretests were taken and the data recorded, E gave the following instructions:

Your task now is to place your right (left) index finger in the upper right corner of the front face of the stimulus and begin tracing the front contours of the object as accurately as you can. You will do this for a period of fifteen minutes. I will tell you after each five minute segment has passed. At the end of the fifteen minute period you will again align the red points of light to the vertical four times. If at any time you do not feel that you can comply with these instructions as I have stated them, please let me know. It is imperative that you follow these instructions closely. Do you have any questions?

Upon completion of the exposure period, Ss were given the visual post tests. In order to keep delay duration to a minimum, instructions were very brief:

Your task is now the same as it was in the beginning. Tell me when you perceive the two points to be vertical. Any questions?

Four trials were again run, but this time only the first trial was employed to produce S's post test score. The direction of point rotation was so organized that the last trial of the pretest and the first trial of the post test always involved movement of the points starting from the same direction. This was done to balance the anticipation effect, if any, across these two trials.

The second design involved the largest number of Ss and the greatest number of stimulus-activity combinations. There were three factors: activity, having active, passive, and eye-pace levels; stimulus fields, using those stimulus

fields presented in Figure 3; and the pre-post visual point alignment task.

The preliminary procedures and the first set of instructions were identical with Design 1. However, subsequent instructions depended upon the level of activity in which the S was participating. All Ss in this design received the same treatment up through the pretests. At that point procedure diverged for the different groups. Those Ss in the passive group were given the following instructions:

Your next task will be to stare at or fixate the black dot in the center of the front face of the object. If you are really doing your job, what might happen is that the dot, the object, or your hand might periodically fade in and out. This is natural. You will do this for fifteen minutes. I will tell you after each five minute segment has passed. You will keep your hand perfectly still. At the end of fifteen minutes you will close your eyes. When you open them, you will again align the red points of light to the vertical four times. If at any time you do not feel that you can comply with these instructions as I have stated them, please let me know. It is imperative that you follow the instructions closely. Do you have any questions?

These instructions were given to all "passive" Ss regardless of the stimuli to which they were exposed. Upon completion of exposure and the post tests, the Ss were debriefed and released.

Ss in the paced eye movement condition received the following directions in place of the instructions given to the "passive" group:

After you open your eyes, you will not only see your hand and the object but will note a point of light moving around the front contours of the object. Your next task is to follow the light around those contours with your eyes. You

will do this for fifteen minutes. You will keep your hand perfectly still. I will tell you when each five minute segment has passed. At the end of the fifteen minutes you will close your eyes. When you open them, you will again align the red points of light to the vertical four times. If at any time you do not feel that you can comply with these instructions as I have stated them, please let me know. It is imperative that you follow the instructions closely. Do you have any questions?

As with the previous group, upon completion of exposure and the post tests they were debriefed and released.

The situation for the active trace level in Design 2 was more complicated, however. At this level the data was collected not only for Design 2, but also all the data for Design 4 was acquired at the same time with the same SS. The visual motor or pointing variable was used in Design 4 and this necessitated modification of procedure for the active level of Design 2. Each S received the same preliminary instructions as all the previous SS had. Upon completion of the visual pretest with no prisms in the field, the prisms were put into place and exposure was begun. During the first minute of exposure, SS performed the pointing task twice, moving their index fingers from the midpoint of the stimulus to that point they felt was directly in front of them. This was referred to as the first visual motor measure. Only the second trial was used for analysis. At the end of exposure, in which S was required to trace the front contours of the stimulus, the second visual motor measures were taken. Here only the first trial was later to be analyzed in Design 4. When this had been finished, the prisms were removed from the field and the

four visual post tests were accomplished. The experimental session was terminated in the same manner as it had been done previously.

The instructions given to each active level S after the preliminary directions and visual pretests were:

Your next task will be to place your right (left) index finger on the dot in the middle of the front face of the object. When I say "ready, point", you will point straight ahead as if you are pointing at an imaginary target and trying to keep the tip of your finger lined up with the tip of your nose (E demonstrates). You will do this twice. Each time you point, move your whole hand and forearm until you hit a small cardboard barrier (the protractor used for taking the measurements). Leave your hand there until I ask you to return it to the starting point. At the end of these two trials your next task will begin. Your task now is to place your right (left) index finger in the upper right corner of the front face of the stimulus and begin tracing the front contours of the object as accurately as you can. You will do this for a period of fifteen minutes. I will tell you after each five minute segment has passed. At the end of the fifteen minute period you will again align the red points of light to the vertical four times. If at any time you do not feel you can comply with these instructions as I have stated them, please let me know. It is imperative that you follow these instructions closely. Do you have any questions?

In Design 3 there were also three factors: view vs no view of hand; fields, circle and cube; and the pre-post testing. Preliminary procedures were the same as for the previous experiments. This design required the running of two additional groups which were exposed to the two stimuli without Ss' hands being in the visual field. Exposure was under the "passive" level of activity in which Ss were required to fixate the midpoint of the stimuli. To make up the entirety of this design, data from the two new groups was compared with

that collected for the two groups in Design 2 who experienced the passive-cube and passive-circle combinations. These combinations had required ss to keep their hands next to the stimulus fields during exposure. Instructions used were the same as those for the "passive" groups in Design 2. The dependent variable of concern was again the visual point alignment task.

Design 4 was the first to look at the visual-motor dependent variable. This design contained two factors, the five fields seen in Figure 3, and a measures factor. The latter involved a first and second measure taken during exposure to the prisms and therefore was distinguishably different from the familiar pre-post test used in the first three designs. The data were collected using the 40 ss in the active level of Design 2. The procedures and instructions were the same.

Design 5 also employed the visual-motor dependent variable. It contained two factors: an eye factor, open vs closed; and the measures factor. One additional group of eight ss was run. The procedure was the same as in Design 4 except that ss were instructed to keep their eyes closed during the pointing task. They then proceeded through an active exposure period tracing the front contours of the cube stimulus field. The second measures were then taken. The visual point alignment task was used and the data collected but not analyzed. This was done to keep this new group similar to the group from Design 4 with which it was to be compared. This specifically was the active-cube group, which had also been used in Design 2. In the latter, however, only the visual

data had been employed whereas in Designs 4 and 5 only the visual-motor data was used.

RESULTS

The following analyses were done in order to test the hypotheses stated in the last part of the introduction to this paper. Two dependent variables were employed over the series of experiments. The first was a completely visual task in which Ss were required to line up the two red points with their subjective estimate of the vertical. The second visual-motor or pointing task required Ss to move the index finger of their dominant hand from the fixation point in the center of the stimulus to an unseen point directly in front of them.

Scores were recorded in degrees from an origin, gravitational vertical or that point directly in front of an S's body depending on which variable was being employed. Directionality or sign was attached to each score relative to the direction of prism rotation. For both variables an individual error score was given a sign by the following formula: suppose that rotation was to the right; a response to the right of zero was positive while a response to the left of zero was negative. Pre-post difference scores were used in the correlational work to be reported later. They were given signs by two different techniques. The formula for the visual variable was: given the last pretest score, if the first post test score represented a shift in the direction of rotation, the difference score was positive. If, however, the shift was in the opposite direction, then the score was negative. The formula for the visual-motor variable was just the opposite of the above. Thus, a pre-post shift in the direction of rotation would be negative and a shift

in the opposite direction would be positive. Admittedly this can be somewhat confusing. However, the two formulas were different for the following reason. It was noted that in pilot work most visual shifts were in the direction of rotation while visual motor shifts were not. It was felt that the above formulas would best show this by, hopefully, producing a positive correlation between the difference scores of the two variables.

The results of the first design were considered crucial for those aspects of this research series which utilized the visual dependent variable. The purpose of this experiment was to see if the optical system in an unrotated state produced any treatment variance as compared with the variance produced when the system was rotated. Table 2 indicates the mean errors in the rotation and no rotation conditions.

TABLE 2

Mean Error for Rotation and No Rotation in Design One

| First Factor | Second Factor | |
|------------------------------|----------------------|-----------------------|
| | b ₁ (pre) | b ₂ (post) |
| a ₁ (rotation) | 1.00 | 4.69 |
| a ₂ (no rotation) | 1.38 | 2.00 |

The data employed was taken under the active-trace condition using the cube as a stimulus. Table 3 presents a summary of this two x two analysis of variance. The significant interaction of the rotation and pre-post factors in the first

TABLE 3
Analysis of Variance for Design 1

| Source | df | ms | F |
|------------------------------------|----|-------|----------|
| <u>Between Ss</u> | | | |
| A (rotation <u>vs</u> no rotation) | 1 | 10.70 | 2.42 |
| <u>Ss</u> within groups | 14 | 4.42 | |
| <u>Within Ss</u> | | | |
| B (pre-post) | 1 | 37.20 | 43.71*** |
| AB | 1 | 18.75 | 22.03*** |
| B x <u>Ss</u> within groups | 14 | .851 | |

***p < .001

design required tests of simple main effects. This was accomplished and the results appear in Table 4. The results from Design 1 were completely according to prediction for the visual dependent variable and provided a justification for doing the remainder of the research. While the post test means were significantly different from one another, the pretest means were not, indicating that the two groups did not bring with them such differences that would make them perform differently by chance rather than because of the different treatments. It was apparent that the rotated optical system resulted in a significant increase in mean error while the optical system when not rotated produced no increase. Upon completing the first design successfully, the way was cleared to proceed to the second.

The second design consisted of a two x three x five analysis of variance to examine the pre-post effects for three levels of activity and five stimulus fields. Table 5 presents a summary of the mean errors that were analyzed. Table 6 is a presentation of the analysis of variance that was computed. It was evident that a large pre-post difference existed and was significant at the .001 level. This indicated that ss experienced what could be referred to as an adaptive shift regardless of the stimulus-activity combination with which they were presented.

The relatively large activity by pre-post ($.05 < p < .10$) term approached significance, and this result indicated that the additivity of the activity and pre-post main effects was

TABLE 4
Simple Main Effects from the AB Interaction in Design 1

| Source | df | ms | F |
|---|----|-------|----------|
| Rotation <u>vs</u> no rotation at pretest a(b ₁) | 1 | .565 | .214 |
| Rotation vs no rotation at post test a(b ₂) | 1 | 28.89 | 10.95** |
| Error (<u>S</u> s within cell) | 28 | 2.637 | |
| Pre-post test under rotation b(a ₁) | 1 | 54.39 | 63.91*** |
| Pre-post test under no rotation b(a ₂) | 1 | 1.565 | 1.839 |
| Error (B x <u>S</u> s within groups) | 14 | .851 | |

**p < .01

***p < .001

TABLE 5
Mean Error (Degrees) Deviation for Each
Activity-Stimulus Combination in the Second Design

| C ₁ (pre) | | | | | |
|---------------------------|--------------------------|----------------------------------|--------------------------------------|--------------------------|------------------------|
| Activity | Fields | | | | |
| | b ₁ circle | b ₂ random form | b ₃ 3-d random form | b ₄ square | b ₅ cube |
| a ₁ (passive) | .75 | .75 | 1.69 | .81 | 1.31 |
| a ₂ (eye pace) | 1.31 | .94 | 1.87 | .06 | .50 |
| a ₃ (active) | .625 | 1.44 | 1.94 | 2.00 | 1.00 |
| C ₂ (post) | | | | | |
| Activity | Fields | | | | |
| | b ₁ circle | b ₂ random form | b ₃ 3-d random form | b ₄ square | b ₅ cube |
| a ₁ (passive) | 4.375 | 2.44 | 3.81 | 2.50 | 4.00 |
| a ₂ (eye pace) | 2.50 | 2.375 | 4.375 | 1.00 | 2.19 |
| a ₃ (active) | 3.31 | 4.40 | 2.875 | 4.75 | 4.69 |

TABLE 6
Analysis of Variance for Design 2

| Source | df | ms | F |
|-----------------------------|-----|--------|-----------|
| <u>Between Ss</u> | | | |
| A (activity) | 2 | 19.785 | 1.86 |
| B (fields) | 4 | 5.52 | .52 |
| AB | 8 | 9.27 | .87 |
| <u>Ss</u> within groups | 105 | 10.65 | |
| <u>Within Ss</u> | | | |
| C (pre-post) | 1 | 283.84 | 127.28*** |
| AC | 2 | 6.17 | 2.77* |
| BC | 4 | 1.90 | .85 |
| ABC | 8 | 3.17 | 1.42 |
| C x <u>Ss</u> within groups | 105 | 2.23 | |

***p < .001

*p < .10

somewhat questionable and should be interpreted cautiously. Therefore, it was thought that the pre-post effects probably made differential contributions to the accountable variability in the system, depending on their level of activity. Figure 4 gives such an indication of differential effects across the different levels of activity. The simple main effects were thus analyzed in order to review the relative magnitude of their F ratios. When the same null hypothesis F distribution exists for a number of F tests, the larger an F ratio becomes, the greater the proportion of accountable variability relative to that obtained by chance. The latter is indicated by the error term in the denominator of the ratio. Table 7 represents the analysis of simple main effects. It is clear that there was approximately a three to one ratio from the active condition to the eye pace condition and a two to one relationship between the passive level and the eye pace. The latter provided the least amount of accountable variability. Although still significant at the .01 level, it did not even approach the .001 level which was exceeded by both of the other activity conditions.

The purpose of Design 3 was to check the importance of the sight of a body part for adaptation. It involved a two x two x two analysis of variance of the visual dependent variable. The first factor was composed of two fields, a circle and a cube. The second involved the view of the hand compared to the situation where ss could not see their hand. The third factor was the familiar pre-post test. Table 8 presents a summary

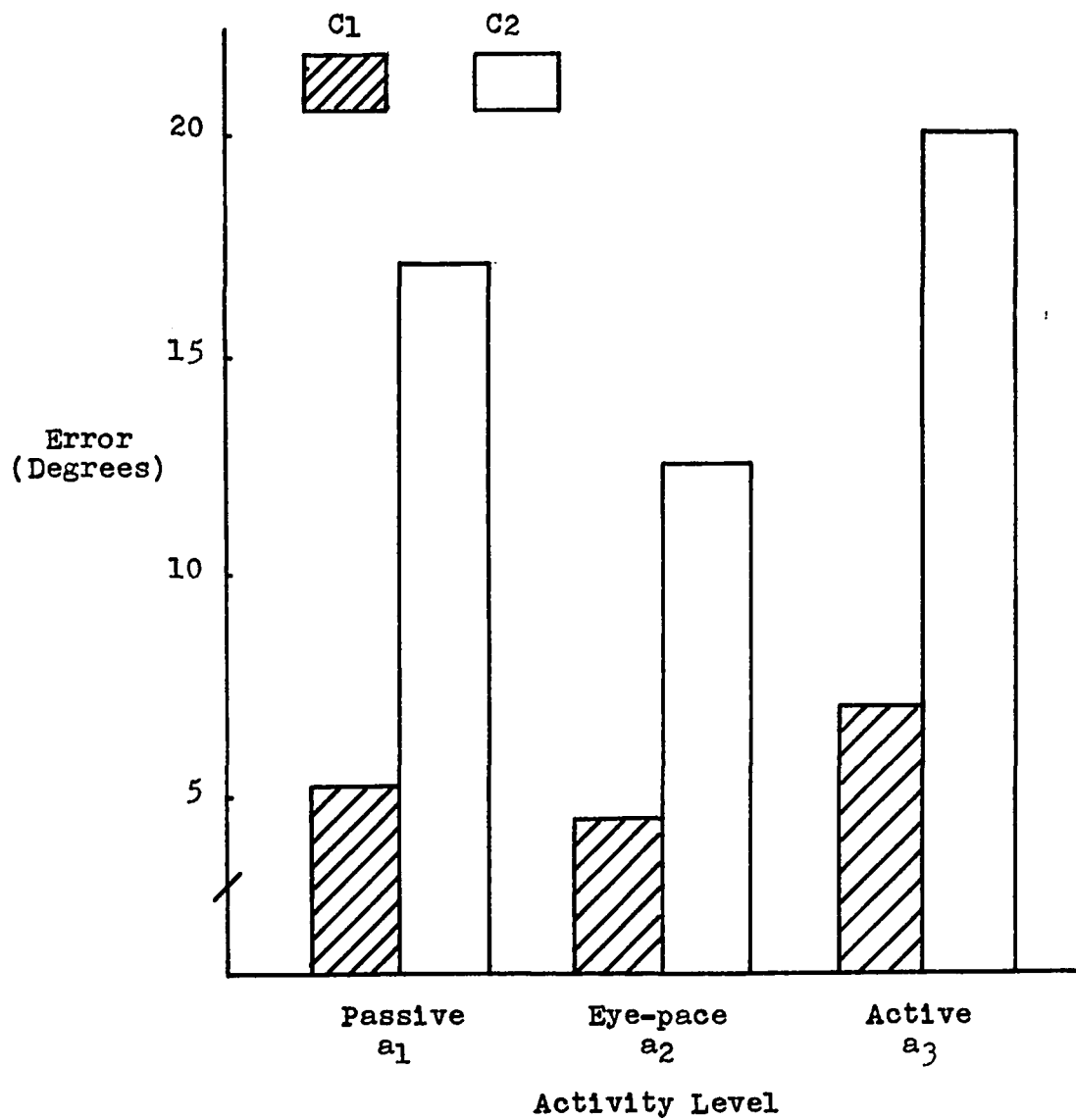


Fig. 4. Bar graph of AC interaction in Design 2.

TABLE 7
 Comparison of Simple Main Effects from AC
 (Activity x Pre-post) Term in Design 2

| Source | df | ms | F |
|---|-----|--------|----------|
| C at passive level (a_1) | 1 | 111.62 | 17.33*** |
| C at eye pace level (a_2) | 1 | 48.05 | 7.46** |
| C at active trace level (a_3) | 1 | 136.5 | 21.20*** |
| Error term (pooled from ms within and ms between) | 105 | 6.44 | |

**p < .01

***p < .001

TABLE 8
Mean Error (Degrees) for Each View-Field
Combination in Design 3

| C ₁ (pre) | | |
|-------------------------|-----------------------|--------------------------|
| First Factor | Second Factor | |
| | b ₁ (view) | b ₂ (no view) |
| a ₁ (circle) | .75 | 1.81 |
| a ₂ (cube) | 1.31 | 2.50 |
| C ₂ (post) | | |
| First Factor | Second Factor | |
| | b ₁ (view) | b ₂ (no view) |
| a ₁ (circle) | 4.375 | 2.625 |
| a ₂ (cube) | 4 | 4.94 |

of the mean error produced by this design and Table 9 summarizes the subsequent analysis of variance. The pre-post rotation factor was the only main effect which was significant. This was qualified in part by the interaction of this factor with the view of hand factor.

An analysis of simple main effects from this interaction was not very informative. All that it indicated was that the pre-post shifts existed with and without the view of the hand. The shift with the view of hand was much stronger, however. These considerations led to a reexamination of Table 9 where it was noted that the main effects and the two factor interaction were further qualified by the field by view by pre-post (ABC) interaction ($.05 < p < .10$). It was thought that an examination of simple--simple main effects from this interaction could provide additional information. This was definitely the case as can be seen in Table 10. Without the view of the hand those ss who used the circle stimulus produced no pre-post rotation shift. When the view of hand was added in the field with the circle, a rather large shift appeared. In contrast, those ss exposed to the cube demonstrated a pre-post rotation shift regardless of whether they were allowed to use their hand or not.

The data for Design 4 were collected at the same time as those for Design 2 (under the active level, a_3) using the visual-motor or pointing variable. It will be remembered that measures were taken on this variable at the beginning of exposure after the visual pretest and at the end of exposure

TABLE 9
Analysis of Variance for Design 3

| Source | df | ms | F |
|-----------------------------|----|-------|----------|
| <u>Between Ss</u> | | | |
| A (fields) | 1 | 10.15 | 1.74 |
| B (view <u>vs</u> no view) | 1 | 2.06 | .353 |
| AB | 1 | 7.92 | 1.36 |
| <u>Ss</u> within groups | 28 | 5.83 | |
| <u>Within Ss</u> | | | |
| C (pre-post) | 1 | 91.44 | 45.27*** |
| AC | 1 | .48 | .23 |
| BC | 1 | 9.38 | 4.64** |
| ABC | 1 | 6.56 | 3.25* |
| C x <u>Ss</u> within groups | 28 | 2.02 | |

***p < .001

**p < .05

*p < .10

TABLE 10
Simple-Simple Main Effects from ABC Term
in Design 3

| Source | df | ms | F |
|---|----|--------|-----------|
| Pre-post, circle with view of hand C(a_1b_1) | 1 | 52.56 | 13.408*** |
| Pre-post, cube, with view of hand C(a_2b_1) | 1 | 28.89 | 7.37* |
| Pre-post, circle, without view of hand C(a_1b_2) | 1 | 2.641 | .673 |
| Pre-post, cube, without view of hand C(a_2b_2) | 1 | 23.771 | 6.06* |
| Error (pooled) | 28 | 3.92 | |

*p < .05

***p < .001

before the visual post test. Therefore, all measures were done while Ss were exposed to prism rotation. Table 11 is a presentation of the mean errors resulting from these measures. It was apparent that the magnitude of these effects was considerably different from the data accumulated from the visual dependent variable. The negative signs meant that in practically all cases, Ss' responses at both the beginning and the end of exposure were in the opposite direction of rotation, while in comparison responses on the visual task were primarily in the same direction as the rotation. A five x two (fields x measures) analysis of variance was conducted. The two level factor is referred to as the measures factor to distinguish it from the visual pre-post arrangement done in the previous experiments. The results of the analysis are seen in Table 12. Neither factor B (measures), factor A (fields) nor the AB (fields x measures) interaction were significant. It will be remembered that measures for this analysis were taken at the beginning of and end of exposure with the fields present. This may explain the lack of a difference in the measures variable. What the latter indicated, however, was that no adaptive shifts occurred for the visual motor variable with the rotated field visible during both testings.

A Pearson product-moment correlation was computed on the pre-post difference scores of the visual variable from level a_3 (active trace) of Design 2 and the difference scores from the measures variable in Design 4. The obtained correlation was $-.248$. This low relationship was probably due at

TABLE 11
Mean Error (Degrees) on Visual Motor Task in Design 4

| Second Factor | | |
|-------------------------|---------------------|---------------------|
| First Factor | b_1 (1st measure) | b_2 (2nd measure) |
| a_1 (circle) | -20.375 | -19.125 |
| a_2 (random form) | -14.625 | -15.375 |
| a_3 (3-d random form) | -16.375 | -25.250 |
| a_4 (square) | -23.500 | -24.875 |
| a_5 (cube) | -13.810 | -16.875 |

TABLE 12
Analysis of Variance for Design 4

| Source | df | ms | F |
|-----------------------------|----|--------|------|
| <u>Between Ss</u> | | | |
| A (fields) | 4 | 240.5 | 1.88 |
| <u>Ss</u> within groups | 35 | 127.2 | |
| <u>Within Ss</u> | | | |
| B (measures) | 1 | 131.35 | 2.86 |
| AB | 4 | 59.32 | 1.29 |
| B x <u>Ss</u> within groups | 35 | 45.84 | |

least in part to the lack of variability in the measures factor of the visual-motor task. It is questionable whether this task is a measure of any thing as used in this study. In a subsequent study it may be more relevant to try out this variable without the stimulus fields being present during measurement.

The next design was concerned with the effects of seeing one's hand when the S was performing the visual-motor pointing task. A comparison was made on that variable between a group performing with their eyes open and another who functioned with their eyes closed. It will be recalled that both groups experienced a fifteen minute active-trace exposure period between the first and second measures. Table 13 provides the mean error scores under these two conditions.

TABLE 13
Mean Error Scores in Design 5

| First Factor | Second Factor | |
|------------------------------|------------------------------|------------------------------|
| | b ₁ (1st measure) | b ₂ (2nd measure) |
| a ₁ (eyes open) | -13.810 | -16.875 |
| a ₂ (eyes closed) | -7.625 | -11.500 |

While it might seem from examining this table that a difference exists, an analysis of variance (two x two with repeated measures on the measures factor) in Table 14 demonstrates no such difference. The reason for this was the phenomenally large error terms which cancelled all possibility of finding

TABLE 14
Analysis of Variance for Design 5

| Source | df | ms | F |
|--------------------------------|----|--------|------|
| <u>Between Ss</u> | | | |
| A (eyes open <u>vs</u> closed) | 1 | 267.38 | 1.1 |
| <u>Ss</u> within groups | 14 | 242.69 | |
| <u>Within Ss</u> | | | |
| B (pre-post) | 1 | 96.25 | .97 |
| AB | 1 | 1.33 | .013 |
| B x <u>Ss</u> within groups | 14 | 98.43 | |

significant treatment variance. The error variance was larger for the group which closed its eyes although the mean error scores were of smaller magnitude as seen in Table 13. The obtained error variances across the pre-post test were 69.71 and 275.71 for the eyes open and eyes closed conditions, respectively. It was clear from Table 14 that most of the variability in the system was due to error variance. The group which closed its eyes when performing the visual-motor task also provided visual point alignment data. The difference scores for the two variables were again correlated. Since there were only eight pairs of scores, the non-parametric Spearman Rho statistic was used. The obtained result was $-.120$. This was viewed as being in accord with the correlation computed from Design 4, in both magnitude and direction.

A sixth design and analysis, originally not planned in the program, was called for from the results obtained in Designs 1 through 3. In those designs, although four pre and four post trials were run on the visual point alignment task, only the last pretest and the first post test were employed in the analyses of data. The first trial of the pretest was begun in the direction opposite to that of rotation. The trials were then begun in alternating sequence such that the last trial of the pretest was begun from the direction of rotation. The first trial of the post test was also begun from the direction of rotation and the subsequent three trials were alternated. Thus in both pre and post tests, two trials were run from the same direction as the rotation and two from

the opposite direction. A vital factor to note, however, was that in Designs 1 through 3 on the visual variable, only the last trial of the pretest and the first trial of the post test were utilized. These were the key trials.

There were several reasons for the use of key trials. First, it was questionable what an average of two trials would mean in terms of adaptation. It would represent simply one level of greater abstraction from the data. It was also felt necessary to allow Ss practice with the task at the beginning to ensure they had correctly defined it. Finally, there was the possibility that Ss would anticipate the vertical with their verbal responses. It was felt the key trials had to come from the same direction to balance such effects. In an attempt to justify the use of key trials, Design 6 was effected.

The data were taken from those 40 Ss that participated in the active level of Design 1. The data for each S were reorganized in that his two responses in the pretest trials where the points were rotated from the direction of rotation were pooled. The same was done for the trials from the opposite direction. This process was repeated for the post test, thus reducing the number of measures on a single S from a total of eight (four pre and four post) to a total of four. The analysis involved a four x two x two (fields by trials--same, opposite by pre-post) analysis of variance. A summary table of means of the data obtained appears in Table 15 and a summary of the analysis in Table 16.

TABLE 15
Mean Errors (Degrees) for Design 6

| c ₁ (pre) | | | c ₂ (post) | | |
|----------------------|------------------------------|--------------------------|-----------------------|------------------------------|--------------------------|
| Fields | Trials | | Fields | Trials | |
| | b ₁ (opposite) | b ₂ (same) | | b ₁ (opposite) | b ₂ (same) |
| a ₁ | -6.31 | .940 | a ₁ | -3.375 | 4.875 |
| a ₂ | -2.44 | 3.810 | a ₂ | 1.310 | 6.500 |
| a ₃ | -5.31 | 3.750 | a ₃ | -2.440 | 4.625 |
| a ₄ | -3.94 | 3.625 | a ₄ | 1.690 | 7.560 |
| a ₅ | -.75 | 2.125 | a ₅ | 2.940 | 6.440 |
| Mean | -3.75 | 2.650 | Mean | .025 | 6.000 |

It was evident from this analysis that there was what appeared to be a significant anticipation effect. There was a clear difference between those trials in which the points were rotated from the direction of rotation and those trials in which they were rotated from the opposite direction. This was indicated from the differences between the means (same-opposite) that existed within the pretest and also within the post test. The rotation effect was demonstrated by an increase in mean error from the pre to the post tests, regardless of whether movement of the points began in the same or in the opposite direction of rotation. Note in Table 15 that the shift from the pre-opposite condition (c₁b₁) to the post-opposite (c₂b₁) was of the same magnitude as that from the pre-same (c₁b₂) to post-same (c₂b₂) situations. This justified the use

TABLE 16
Analysis of Variance for Design 6

| Source | df | ms | F |
|------------------------------|----|--------|----------|
| <u>Between Ss</u> | | | |
| A (fields) | 4 | 86.86 | 1.16 |
| <u>Ss</u> within groups | 35 | 75.03 | |
| <u>Within Ss</u> | | | |
| B (trials) | 1 | 1531.4 | 85.65*** |
| AB | 4 | 27.67 | 1.55 |
| B x <u>Ss</u> within groups | 35 | 17.88 | |
| C (pre-post) | 1 | 507.65 | 70.21*** |
| AC | 4 | 6.44 | .89 |
| C x <u>Ss</u> within groups | 35 | 7.23 | |
| BC | 1 | 1.82 | .28 |
| ABC | 4 | 2.73 | .41 |
| BC x <u>Ss</u> within groups | 35 | 6.59 | |

***p < .001

of key trials where only those trials coming from the same direction were considered. Hopefully the anticipation was balanced across such trials but at least spurious results were avoided. Such results might have been obtained had trials from opposite directions been compared across the pre-post rotation factor. It was also evident that the pre-post rotation shift held up even when all trials were considered.

DISCUSSION

The results from this series of experiments make several possible conclusions apparent. First, a pre-post rotation shift was reliably produced with the visual point alignment variable. Within the confines of these experiments the shift was not field specific when SS could see their hands through the prisms. Field effects should be considered, however, when the various fields provide the only sources of information. The pre-post rotation effect did vary as a function of exposure activity and sight of a body part. This was indicated by the larger amount of accountable variability for the active and passive conditions in comparison to the eye-pace situation and to the view--no view differences relative to the fields employed. The visual-motor variable as used did not produce reliable shifts and correlated rather poorly with the visual variable, indicating that the two dependent variables were measuring different things. It was also found that while sight of a body part, specifically the hand, was not a necessary condition for adaptation to some fields, it may be to others. It may also be a contributing factor to the magnitude of pre-post rotation shifts. Finally, it was found that there was indeed an anticipation effect in the point alignment task, but that the adaptive shift occurred in spite of this confounding variable. In light of these conclusions it is now necessary to examine the contribution of each experiment to the empirical and theoretical framework of this paper.

These experiments were done with a novel organization

of procedure. Few researchers had attempted rotation studies while severely limiting the freedom of Ss' movement during exposure. Further, the optical system used in the studies reported in this paper was different in design and capability than apparatus used by other researchers. There were a few problems with the system which were unavoidable unless endless delay was accepted in dealing with the manufacturer. Specifically, one edge of the prism nearest to the S was partially visible in the field. When the system was rotated, this edge was also rotated and may have contributed to the treatment variance, but the results of Design 3 tend to indicate this was not likely.

What we had to find out with the first design was whether the system would produce anything that looked like treatment variance when it was in an unrotated state. In other words, was the system itself a contributor to the effects that should have been a function of rotation itself? The interaction of the Pre-post and the Rotation Factors provided hope that the research could continue. Post testing confirmed this. The post rotation measures were significantly different, and there was a pre-post rotation shift only for the group which had viewed the stimuli rotated by 30 degrees. This meant that without rotation Ss' perceptual abilities remained unchanged. The agent of change was thus clearly defined. This experiment while of extreme importance to the remaining studies provided little in terms of theoretical considerations. The way was then clear to conduct experiments that might be more productive

in that area.

The goals of Design 2 were ambitious. Several investigators had alluded to the importance of the stimulus field but no one had systematically attempted to control it (Kohler, 1964; Rock, 1966). Held and Rekosh (1963) and Mikaelian and Held (1964) found that if you adequately impoverish available stimulus information, you can reduce adaptive effects by a large amount. There seems to be a logical endpoint to this, however, in that Ss must see something through their prisms for the distortion to have any effect on their perceptual systems. The minimum they must see has as yet to be determined although Mikaelian and Held (1964) certainly approaches it with their dimly-lit sphere field. They produced significant shifts under these conditions only when Ss were in active locomotion. Passive Ss produced changes that were "about zero". In Design 2 the treatment variable due to the Field Factor was negligible in magnitude, and the variance from the activity variable was also not significant. The Pre-post Rotation Factor seemed to hold regardless of the stimulus-activity combination. The pre-post rotation by activity interaction approaches significance at the .05 level. This meant, as indicated earlier, that the pre-post rotation factor had to be interpreted cautiously, because it made the additivity of activity levels questionable.

An analysis of simple main effects in the Pre-post Factor at the three levels of activity provided some interesting results. There was a great deal more accountable variability

in the Pre-post Factor at both the active and passive levels than at the eye-pace condition. It had been apparent from the earliest ss that the eye-pace condition was less reliable and produced smaller shifts than the other two. It was surprising that the passive condition was so similar to the active condition. While this would have been predicted by such investigators as Rock (1966), Mack (1967), Templeton et al. (1966), and Weinstein et al. (1964), Held (1961) would have predicted that the active trace condition would produce more error than the passive condition.

There are several possible reasons for the lower performance on the eye-pace task. There were apparatus problems from the beginning. A system using lights and timers was prohibitively expensive. It was decided to utilize a Lafayette Pursuit Unit with field templates as described earlier. While this did provide a visual tracing target for the ss, its intensity was too low. It was therefore necessary to lower the overhead illumination to one-half of what was used in the other two levels of activity. Then the light target and the stimulus were both clearly visible. Another possible reason for the lower performance on the eye-pace condition may involve the nature of the task itself. It is highly possible that adaptation occurs in the average S as a function of the reward-cost balance in any experimental situation. Given a situation where S must locomote while wearing distorting lenses, he has several reasons to adapt. He can trip over his own feet and on any available object. This is no doubt unpleasant and will

lead to attempts to improve perceptual-motor coordination. Given a situation where less ambitious movement is required, the reinforcement may involve simply a reduction in uncertainty about the environment. Such a reason for learning to perceive was suggested by Gibson (1966). Suppose, however, we provide Ss with a third alternative and an attractive one at that. We remove all costs and make the only reinforcement the avoidance of boredom by the completion of a task. We give the S a simple task that he can submerge himself in, and dream about whatever it is that Ss dream about. There are no costs, in that he does not have to keep his hand on the target of the stimulus contours and he does not have to combat as much boredom as the S required to fixate the center of a stimulus. All S has to do is follow a point of light; he can easily and effortlessly tune out much of the stimulus information. Many Ss reported using cognitive coping by thinking about something else. While this was also done at the other two levels, it may have had less of an effect. Ss in the active level had to attend to the stimulus. Ss in the passive level had more boredom to handle. Many reported some eye-movement, especially to the hand which was in the field. The relevance of the view of hand was indicated by Design 3 which was accomplished with the passive level of activity. It was found that with the circle as a field the sight of hand was crucial for a pre-post shift to occur. It is possible that had the eye-space level of activity been employed, the results may have been somewhat different in that the eye-space task might have distracted Ss from the information available

from the sight of their hands. To pursue this hypothesis further would require a replication of Design 3 with alternative activity levels (i.e. eye-pace) and perhaps additional fields to provide as much data as possible.

In both the passive and eye-pace conditions Ss could control their eye movements without E's knowledge. It is recommended that in future research an eye camera be used if appropriate to the experimental design. At least then Ss could be pooled in a post hoc manner into groups according to how well they obeyed the instructions. While most Ss seemed to sincerely attempt the passive instructions, most reported some breaches of response. All did report the subjective phenomena to be expected from a fixating S. Stimuli faded in and out wholly or in part, and their dominant eyes often watered. In designing this experiment it was realized that some eye movement would probably occur. Again an eye camera seems the best answer.

While the passive level of activity was not significantly different from the active, it was slightly smaller in magnitude. This may in part have been due to the difference in the reward-cost balance between the two levels. In the passive condition there were minimal costs in that S did not perform any tracking. He was only presented with a novel situation in which he reduced uncertainty and probably utilized information in many cases without knowing it.

The fields variable in Design 2 produced a lack of treatment variability. It is possible that the allusions made

by Kohler (1964) and Rock (1966) were in error and adaptation is not field specific. This conclusion is hardly justifiable on the basis of the data. It involves nothing less than the acceptance of the null hypothesis. There are several alternatives which lead to further research. I may not have used the correct fields to bring out a stimulus effect. This seems unlikely because of the results of Design 3, however, where two fields produced differential results when sight of hand was eliminated. Rock (1966) suggested that the key might be familiarity with stimuli. It still seems logical that if Ss had never seen a stimulus, they could not define it as distorted. So one must immediately ask what occurred with the so-called random forms. Ss may have read something into them, but this is not probable, for no Ss reported them as familiar. A more logical reason involves two sources of information which each S had available to him during the prism exposure. The first involved that prism edge mentioned earlier. While only one S reported noticing it, many may have used it without awareness. The results of Design 3 make this questionable, however. The second reason is also interesting. In the introduction it was recalled that Mack and Rock (1968) felt sight of a body part was not a reliable source of information. Quinlan (1970) showed that viewing the body could affect adaptation.

Before continuing the discussion of Design 2, it would be informative to review the outcome of Design 3, the results of which bear closely upon these points. The third design was developed for the express purpose of finding what role viewing

the hand in the field had within the constraints of this experimental situation. The examination of the fields by view by pre-post (ABC) interaction provided clear evidence for the hypothesis I will develop in the next paragraph. It demonstrated that with a low information field such as the circle, the sight of hand greatly increased the degree of adaptive shift. With a well-structured, informative field like the cube, such an increase was not obtained. There was enough information in the cube already for adaptation to occur. When the hand was added, apparently Ss continued using the cube and the hand had only a slight additional effect.

It may be that viewing the body along with other stimuli has certain differential effects depending on the stimuli and even perhaps on the nature of movement allowed. Quinlan (1970) noted that Mack and Rock (1968) may not have allowed adequate movement to obtain body view effects. While my thinking is speculative, it may be worth carrying it one step further. Suppose that as an S you are exposed to a given field, not allowed to move your head and can also see part of your body. You are deprived of movement-related information, or in Held's (1961) terms, reafference as a result of movement. There are three possible sources of visual information you can attend to: the stimulus, your hand, and extraneous material such as the prism edge or a spot of dust on the glass. Given a random unfamiliar form or a low information form like the circle you attend to the other two sources either intentionally or not. This brings up your adaptive shift to a certain level. Should you

be exposed to a square or a cube, you would have much of the information you need to adapt. Your performance could then be a function of the reward-cost balance provided by what else you had to do besides look at the stimulus. The sight of your hand and the extraneous information could then provide three potentials. It may have no effect on what you do with the stimulus. It may enhance the change in your perceptual ability or it may actually decrease the change in that it detracts your attention from a potentially more effective source of information. These are empirical questions which should be dealt with in the future.

The fact that pre-post shifts occurred is significant in that Ss were deprived of a key source of information-head movement. Although they could move their eyes in relation to the prisms, they could not move their heads or the prisms in relation to the stimuli. Most investigators (i.e. Gibson, 1933; Rock, 1966; Ebenholtz, 1966) have found interocular transfer with or without head movement. However, head movement seems to be essential for intermanual transfer (Harris, 1965; Hamilton, 1964). Both Ebenholtz (1968), a follower of Held's reafference hypothesis, and Rock (1966) see movement in relation to the stimuli as important, because it provides a flow of stimulation across the retina. How the use of this information is interpreted depends on which theory one accepts. Ebenholtz (1968) would feel active movement was necessary while Rock (1966) would only require that S have knowledge of the nature of this movement. The reason for this theoretical digression is this. In those

studies where stimulus effects on adaptation have been alluded to, control of movement was loose. If head-prism movement relative to the stimuli had been allowed, it may have enhanced the pre-post shifts or even permitted the appearance of field effects. A technique for controlling head movement in adaptation research will be discussed later.

The next question to ask is obviously whether this research supports either the information theorists or those who hold the reafference hypothesis. At first glance, it would be easy to fall into the trap of accepting the null hypothesis that there were no differences between the levels of activity. The followers of the reafference hypothesis expected such a difference and invariably found it (Held, 1961; Held & Freedman, 1963; Held & Gottlieb, 1958; Held & Hein, 1958, 1963; Held & Rekosh, 1963; Mikaelian & Held, 1964). It would be folly to disclaim Held's work and that of his students on the basis of one experiment in which no significant activity factor appeared. When such an event occurs, there are several reasons that could be offered. There are design differences between Held's work and this current series of studies which can not be ignored. Design 3 in this series made it apparent that sight of a body part could be important to adaptation. While some of Held's work had sight of a body part involved (i.e. Held & Gottlieb, 1958), it was mostly displacement research, which no doubt is dissimilar to rotation and inversion in terms of what requirements and reward-cost balances it places on the Ss. In Held and Gottlieb's (1958) work Ss saw no fields and

only their hands appeared under the prisms. It is possible that sight of body part acted differentially with the various fields in Design 2 to cancel field effects. The possibility of this was demonstrated in the no-view condition of Design 3.

It is highly likely that to obtain a truly "passive" S an E would be obliged to go to drastic extremes extending from drugs to immobilizing the eyeball. Each technique would represent higher levels of experimental abstraction. Within the conventional framework of adaptation research there is probably no such thing as a passive S. We are all, in Gibson's (1966) terms, active seekers of information. Uncertainty and novelty bother us and we attempt to resolve such situations by learning more about them. Held and his co-workers have no doubt found active-passive differences, at least in part, because their exposure conditions have been more molar in nature. When doing rotation research, Mikaelian and Held (1964) allowed walking during the active phase of the experiment. Mack and Rock (1968) admit that body movement in relation to stimuli is informative and facilitates adaptation. Furthermore, much of Held's active-passive differences have been found with displacement research. As mentioned in the introduction to this paper, it is still too early to take the similarities between different forms of adaptation research for granted and simultaneously ignore the differences. Comparisons are difficult even if for no other reason than the fact that the units of measurement vary from one study to the next.

The phenomenologists and Irwin Rock would not be greatly

upset by my results. They would not even bring forth the accusation of experimental error. They would no doubt conclude that there was information available across the three levels of activity, which must have been sufficient to provide a significant pre-post shift. Rock (1966) does not require active self-directed movement as did Held (1961) as a necessary condition for adaptation. He sees movement only as another source of information to be utilized to its best advantage. It would be falling into the same trap, however, to state that this current research supports Rock completely. It does indicate that even with a minimum amount of movement (the so-called passive condition) strong pre-post rotation effects could be observed.

The Fields Factor in my research brings forth another set of questions. Held (1961) would not have made any predictions to speak of in relation to the importance of the stimuli, except perhaps to remind one of the results of Mikaelian and Held's (1964) study where an impoverished field produced lowered shifts. Kohler (1964) and Rock (1966) both had made allusions to the importance of such factors as field familiarity. It is obviously no easy task to define the term familiarity in operational terms. The only workable technique might be an empirical one in which only randomly constructed figures are used, and E controls the exposure history of each S to each field. There are several possible approaches to the Fields Factor in this research which could be taken assuming the knowledge from Design 3 on the importance of sight of the body. Varying the fields without sight

of the body could be informative. This could lead to research in the alternative field dimensions available. The empirically defined familiarity concept is but one of these. Another would involve some sort of scaling technique along various stimulus dimensions to examine previous exposure to objects in the environment already. This would be more difficult than the previous concept. A final alternative would be to re-examine the activity allowed during exposure. It may be that the restrictions placed on such activity inhibited the appearance of field effects. Granted, this is merely speculation. It would do no harm, however, to explore field effects with other forms of activity and levels of information from view of body parts. An experimental design to do this in part will be presented later in this paper.

Can the controversy between Rock's followers and those of Held be resolved? Coren (1966) suggested a compromise between the proprioceptive theorists (i.e. Harris, 1966) and the phenomenologists (Rock, 1966). Perhaps here I can suggest at least a semantic compromise for Held and Rock. Both theorists utilize a memory mechanism. Rock (1966) discusses the neural trace system and sees adaptation as a function of rebuilding the system. Held (1961) spoke of the neural storage of efferent-reafferent pairs. These pairs were synthesized in a mechanism called the comparator. Not only do both theories require memory but both require feedback. Rock (1966) speaks in terms of information pickup regardless of the modality but primarily visual in nature.

Held's (1961) concept of reafference is also primarily visual, although there seems to be an allusion that some reafferent feedback is sent to the central nervous system from the sensors in the moved extremity. The apparent basic difference between the two theories is based on the importance of movement. The reafference hypothesis demands it, but many researchers seem to find adaptive shifts with a minimum of movement or at least no self-directed movement (Weinstein et al., 1964; Templeton et al., 1966). Rock (1966) and Mack and Rock (1968) see movement as informative only when the S already knows the nature of the movement. It would seem that knowledge of the nature of the movement is similar at least to vicarious self-movement. It seems logical that to account for changes of available information to the retina, the S must know where he is going. Otherwise the information would be misinterpreted and perhaps no adaptation would occur. Again it appears that much controversy is more verbal than actual, but semantic questions often generate interesting research.

To this point we have examined the results derived from using the visual dependent variable. An additional dependent variable was introduced in Designs 4 and 5 to examine the effects of some motor components on the measurement of adaptive shifts. The visual-motor dependent variable, it will be recalled, involved the Ss' pointing directly in front of themselves beginning from the fixation point in the center of the stimulus. The two measures of two trials each were made at the beginning

and end of exposure while S were looking through the prisms. Thus there was a basic difference between the two dependent variables, for the visual point alignment task was done without the prisms. Furthermore, the visual task was done without overt motor involvement on the part of Ss. That there was no adaptive shift from the first to the second measure on the visual-motor task was evident. Although the magnitude of individual error scores were larger than those from the visual variable, they did not reliably change during the period of exposure.

The use of the two dependent variables leads quite naturally into a discussion of the controversy between the proprioceptive theorists and those who postulate higher level or relational changes as the basis for adaptation. The former group was exemplified by Harris (1963, 1965) and in part by Hay and Pick (1966). The latter group involves most everyone else including both Irvin Rock and Richard Held. To the extent that Quinlan (1970) accepted his lack of success with a tactual-kinesthetic variable as support for the visual interpretation of adaptation, then this research too could provide such support. However, this should be done guardedly. Note that Hay and Pick (1966) felt that proprioceptive changes may occur first in the adaptive sequence, then drop out as vision takes over. It is possible that the second measure of the visual motor variable was simply made at the wrong point in the sequence to demonstrate the effect. Also, it must be recalled that the visual-motor task measures were taken with the fields in view while this was not the case with the visual variable.

Design 5, limited as it was in magnitude, informed us that regardless of whether Ss respond on the visual-motor task with eyes open or closed, the results are the same--no pre-post rotation shift. It is probable that field effects would drop out, at least in the pretest, if this experiment had been more broad and included a Fields Factor. This had potential for future investigation. It was evident though that between-S variability increased markedly when Ss responded with their eyes closed. This was due in part to a reduction in stimulus effects, for even in the second measure the best that could be expected was some memory effect of the field. If such a memory effect could be shown, then this type of variable could be moved out of the category of immediate stimulus effects and into the area of more pervasive perceptual change-adaptation. It is apparent that when Ss close their eyes, their responses become less stimulus oriented and more dependent on what they brought with them to the experimental session. This leads one into a concern for individual differences like that of Witkin et al. (1954). What is needed is a perceptual researcher who wants to examine person variables in relation to adaptation. The general conclusion from this variable as with the previous variable is simply that it generates more questions than it answers.

The last experiment, designated as Design 6, was again concerned with data from the visual point alignment task. To reiterate, its purpose was two-fold. First, it was to seek out the anticipation effect if it was present in the dependent

variable. Such an effect would be manifested by Ss if they responded too early as E rotated the points. At least several Ss reported that they felt that they had so responded. It was also important to show that adaptive shifts occurred independent of anticipation. The second purpose was to justify the use of last trial of the pretest and the first trial of the post test. That this was justified at least for the post test was shown in part by Fishkin (1968). This author demonstrated that as time increased from the end of exposure, the magnitude of post exposure effects decreased. For my purposes it was felt adequate proof for using the two key trials if an anticipation effect could be proved to depend on the direction of rotation such that it could be balanced by having only two key trials with the points rotated from the same direction. This was, in fact, what the results of Design 6 indicated. The magnitude of the pre-post shifts was about the same regardless of whether the points were turned from the same or the opposite direction of rotation. This was supported by the fact that no interaction occurred between the Trials (same, opposite) Factor and the Pre-post Factor. Had such an interaction occurred, it could have indicated that the anticipation effect was acting in such a way as to make interpretation of the pre-post rotation shift less clear.

One could question why we study perception under transformation. It is possible it may eventually give us information with meaning for developmental psychology. What is more likely, however, and equally relevant is that studying perceptual dis-

tortion can lead us into the area of man's ability to cope with new stimulus situations. It is evident that man must adapt in many ways to an ever-changing environment. The experimental psychologist must locate not only the variables which induce perceptual changes in us but also what factors will facilitate the most efficient directions of change. One could concede that the research reported in this thesis is very molecular, but we must start somewhere. Even in its molecular state, it does have some applicability beyond the laboratory. For example, we know from adaptation research that people can overcome over time many of the initial problems produced by new, strong eyeglasses. Time, however, is but one variable in adaptation. We must not only isolate and define other appropriate variables but also the dimensions along which they can be manipulated.

The research reported in this thesis raises a number of questions, some of which have already been alluded to. The following concerns for future research have been produced in part by the studies reported here. The two general areas covered in this paper involved the role of activity and the importance of exposure stimuli. There is a question as yet unanswered on the role of head movement in prismatic adaptation. Most workers seem to feel movement is useful but they confine themselves to global levels such as walking and sitting or walking and riding. In discussing the importance of head movement, most authors (e.g. Hamilton, 1964) have seen it as an all or none process. Either the investigator allowed such movement or he did not. What would occur if various amounts of

head movement were allowed an S as he attempted to come to terms with a rotated visual field? One could ask whether the level of adaptation would be a function of increased amounts of such movement. If this were the case, viewing head movement in all or none terms would be ignoring an important source of information.

The problems with exposure stimuli are also complex. For example: on what dimensions should they be scaled and how should they be coupled with levels of activity? Also, what would occur if we initially used a qualitative breakdown such as in the research reported in this paper, then progressed to scaled stimulus dimensions or to an empirically defined dimension, as noted earlier.

The primary problem is the head movement variable. This can be accomplished by developing a new apparatus to consist of three parts. The first will be the rotating optical system which will be built in such a way as to avoid extraneous optical cues. The second will be a helmet upon which this system is mounted and having a secure chin strap to prevent any head movement independent of itself. The third will be a shoulder harness with a grooved template mounted on the S's back. A control rod attached to the helmet will ride the grooves in the template, such that E controls the number of planes in which S can move his head and the extent of movement in each direction. The first experiment would involve six levels of head movement ranging from none at all through four planes to free head movement, while still wearing the apparatus.

S would be seated in a special chair equipped to keep their arms and legs immobile but relatively comfortable. At a fixed distance in front of the S would be a translucent screen from behind which stimuli would be projected. S would be unable to see the edges of the screen because of a large horizontal cylinder placed between him and the screen surface. This would restrict him to a circular visual field. The cylinder and stimuli would be large enough and placed at such a distance (through pilot work) that it would be difficult to examine the stimulus without at least moving the eyes.

The dependent variable would involve two points of light projected on the screen and rotated automatically by a motor mounted on the projector. Pre and post measures would be taken with the prisms set in a no-rotation position. Ss could stop the points from turning when they appeared vertical in one of two ways, either verbally with a voice key or manually with a microswitch. These alternatives could even be conceived of as another variable for further research. The experimental design for this project would involve a six (head--planes) by five (fields) by two (pre-post) analysis of variance. It would appear that the empirical possibilities in the area of adaptation are virtually limitless.

This design just stated is but one of these many possibilities. We have found that as a consequence of prism rotation a change in perceptual response to the subjective vertical was induced. This was first evident in Design 1. It was also supported by the results of Designs 2 and 3. Design 6 indicated

in addition that such a change occurred in spite of anticipation effects. Designs 2 and 3 together had considerable impact for adaptation in terms of visual change. While no field specific differences appeared in Design 2, the results of Design 3 tended to indicate that sight of body parts can be a confounding element when attempting to examine field importance. More research is needed on the relevance of viewing oneself through optical rotating systems. We must study stimulus viewing without sight of the body in the prism field. Further, while a field difference did appear in Design 3 when no body part was in view, this occurred under the passive level of activity, which was the only one used for that design. Replications should be done with other types of activity and additional fields, the latter spaced perhaps on some quantifiable dimension. The results of Designs 4 and 5 provide a contrast for the other experiments. The visual-motor variable would not demonstrate adaptive shifts. Again, sight of a body part could have confounded the results. Work with other motor variables in the future seems essential if a clear resolution to the visual-proprioceptive controversy is ever to be obtained.

REFERENCES

- Allport, F. Theories of perception and the concept of structure. New York: Wiley, 1955.
- Asch, S. E., & Witkin, H. A. Studies in space orientation I: perception of the upright with displaced visual fields. Journal of Experimental Psychology, 1948a, 38, 325-337.
- Asch, S. E., & Witkin, H. A. Studies in space orientation II: perception of the upright with displaced visual fields and with body tilted. Journal of Experimental Psychology, 1948b, 38, 455-477.
- Coltheart, M. Visual feature--analyzers and aftereffects of tilt and curvature. Psychological Review, 1971, 78, 114-121.
- Coren, S. Adaptation to prismatic displacement as a function of the amount of available information. Psychonomic Science, 1966, 4, 407-408.
- Ebenholtz, S. M. Adaptation to a rotated visual field as a function of degree of optical tilt and exposure time. Journal of Experimental Psychology, 1966, 72, 629-634.
- Ebenholtz, S. M. Some evidence for a comparator in adaptation to optical tilt. Journal of Experimental Psychology, 1968, 77, 94-99.
- Ebenholtz, S. M., & Mayer, D. Rate of adaptation under constant and varied optical tilt. Perceptual and Motor Skills, 1968, 26, 507-509.
- Efstathiou, A., Bauer, J., Greene, M., & Held, R. Altered reaching following adaptation to optical displacement of the hand. Journal of Experimental Psychology, 1967, 73, 113-120.
- Ewert, H. Factors in space localization during inverted vision II: an explanation of interference and adaptation. Psychological Review, 1937, 44(2), 105-116.
- Fishkin, S. M. Active versus passive exposure and other variables involved in prismatic hand adaptation. (Doctoral dissertation, University of Colorado) Ann Arbor, Mich.: University Microfilms, 1968. No. 68-14, 220.
- Gibson, J. J. Adaptation, aftereffect and contrast in the perception of curved lines. Journal of Experimental Psychology, 1933, 16, 1-31.

- Gibson, J. J. Adaptation with negative aftereffect. Psychological Review, 1937, 44, 222-244.
- Gibson, J. J. Introduction. In I. Kohler, The formation and transformation of the perceptual world. Psychological Issues, 1964, 3(4), 1-22.
- Gibson, J. J. The senses considered as perceptual systems. New York: Houghton Mifflin, 1966.
- Hamilton, C. Intermanual transfer of adaptation to prisms. American Journal of Psychology, 1964, 77, 457-462.
- Harris, C. Adaptation to displaced vision: a proprioceptive change. (Doctoral dissertation, Harvard University) Ann Arbor, Mich.: University Microfilms, 1963. No. 63-8162.
- Harris, C. Perceptual adaptation to inverted, reversed and displaced vision. Psychological Review, 1965, 72, 419-444.
- Hay, J. C., & Pick, H. L. Visual and proprioceptive adaptation to optical displacement of the visual stimulus. Journal of Experimental Psychology, 1966, 71, 150-158.
- Held, R. Exposure history as a factor in maintaining stability of perception and coordination. Journal of Nervous and Mental Diseases, 1961, 132, 26-32.
- Held, R., Efstathiou, A., & Greene, M. Adaptation to displaced and delayed visual feedback from the hand. Journal of Experimental Psychology, 1966, 72, 887-891.
- Held, R., & Freedman, S. J. Plasticity in human sensory motor control. Science, 1963, 142, 455-461.
- Held, R., & Gottlieb, N. Technique for studying adaptation to disarranged hand-eye coordination. Perceptual and Motor Skills, 1958, 8, 83-96.
- Held, R., & Hein, A. Adaptation of disarranged hand-eye coordination contingent upon re-afferent stimulation. Perceptual and Motor Skills, 1958, 8, 87-90.
- Held, R., & Hein, A. Movement produced stimulation in the development of visually guided behavior. Journal of Comparative and Physiological Psychology, 1963, 56, 872-876.
- Held, R., & Rekosh, J. Motor sensory feedback and the geometry of visual space. Science, 1963, 141, 722-723.

- Helmholtz, H. Treatise on physiological optics. (Translated from third German edition; J. P. C. Southall, Ed.) Vol. 3. Menasha, Wisconsin: Banta, 1925. Pp. 242-252.
- Helson, H. Theoretical foundations of psychology. Princeton, N. J.: Van Nostrand, 1951. Pp. 377-385.
- Helson, H. Adaptation level theory. New York: Harper, 1964.
- Hochberg, J. On the importance of movement-produced stimulation in prism-induced aftereffects. Perceptual and Motor Skills, 1963, 16, 544.
- Kohler, I. The formation and transformation of the perceptual world. Psychological Issues, 1964, 3(4).
- Ludvigh, E. Possible role of proprioception in the extraocular muscles. Archives of Ophthalmology, 1952, 48, 436-441.
- Mack, A. Perceptual adaptation to a rotated visual field. (Doctoral dissertation, Yeshiva University) Ann Arbor, Mich.: University Microfilms, 1966. No. 66-7, 663.
- Mack, A. The role of movement in perceptual adaptation to a tilted retinal image. Perceptual and Psychophysics, 1967, 2, 65-88.
- Mack, A., & Rock, I. A reexamination of the Stratton effect: egocentric adaptation to a rotated visual image. Perception and Psychophysics, 1968, 4, 57-61.
- Mikaelian, H., & Held, R. Two types of adaptation to optically-rotated visual field. American Journal of Psychology, 1964, 77, 257-263.
- Mortant, R. B., & Beller, H. Adaptation to prismatically rotated visual fields. Science, 1965, 148, 530-531.
- Mortant, R. B., & Harris, J. R. Two different aftereffects of exposure to visual tilts. American Journal of Psychology, 1965, 78, 218-226.
- Pick, H. L., & Hay, J. C. Adaptation to prismatic distortion. Psychonomic Science, 1964, 1, 199-200.
- Quinlan, D. Effects of sight of body and active locomotion in perceptual adaptation. Journal of Experimental Psychology, 1970, 86, 91-96.
- Rierdan, J. E., & Wapner, S. Experimental study of adaptation to visual rearrangement deriving from an organismic-developmental approach to cognition. Perceptual and Motor Skills, 1966, 23, 903-916.

- Rock, I. The nature of perceptual adaptation. New York: Basic Books, 1966.
- Rock, I. When the world is tilt. Psychology Today, 1968, 2, 24-31.
- Singer, G., & Day, R. H. Spatial adaptation and aftereffect with optically transformed vision: effects of active and passive responding and the relationship between test and exposure responses. Journal of Experimental Psychology, 1966, 71, 725-731.
- Snyder, F. W., & Pronko, N. H. Vision without spatial inversion. Wichita, Kansas: University of Wichita Press, 1952.
- Stein, E. The field-dependence-independence construct and visual perception. Unpublished master's thesis, University of New Hampshire, 1970.
- Stratton, G. Some preliminary experiments on vision without inversion of the retinal image. Psychological Review, 1896, 3, 611-617.
- Stratton, G. Vision without inversion of the retinal image. Psychological Review, 1897, 4, 341-360, 363-481.
- Templeton, W. B., Howard, I. P., & Lowman, A. E. Passively generated adaptation to prismatic distortion. Perceptual and Motor Skills, 1966, 22, 140-142.
- Weinstein, S., Sersen, E. A., Fisher, L., & Weisinger, M. Is refference necessary for visual adaptation. Perceptual and Motor Skills, 1964, 38, 641-648.
- Werner, H., & Wapner, S. Toward a general theory of perception. Psychological Review, 1952, 59, 324-338.
- Werner, H., & Wapner, S. The Innsbruck studies on distorted visual fields in relation to an organismic theory of perception. Psychological Review, 1955, 62, 130-138.
- Witkin, H. A., & Asch, S. E. Studies in space orientation III: perception of the upright in the absence of a visual field. Journal of Experimental Psychology, 1948a, 38, 603-614.
- Witkin, H. A., & Asch, S. E. Studies in space orientation IV: further experiments on perception of the upright with displaced visual fields. Journal of Experimental Psychology, 1948b, 38, 762-782.
- Witkin, H. A., Lewis, H. B., Hertzman, M., Machover, K., Meissner, P. B., & Wapner, S. Personality through perception. New York: Harper, 1954.

Wohlwill, J. F. Perceptual learning. In Annual Review of Psychology, 1966, 17, 201-233.